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Assessment of Arctic Grayling Populations in Northern Saskatchewan

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ASSESSMENT OF ARCTIC GRAYLING POPULATIONS IN NORTHERN SASKATCHEWAN

BY

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EXECUTIVE SUMMARY

SITUATION

Grayling are distributed in the northern third of Saskatchewan as far south as the 56th parallel. Their natural habitat consists of clear northern streams where swift flowing waters and rapids abound, and along the rocky shorelines and islands of northern lakes. Grayling occur in localized 'pockets,' and this tendency, plus an attraction to artificial lures, makes the species particularly vulnerable to being overfished. Concern over the status of grayling populations in northern Saskatchewan prompted a two year study of the species in Saskatchewan in 1987 and 1988. Objectives of the survey were to investigate the biology of the grayling and assess population levels before introducing a new management strategy.

RESULTS

During the survey, grayling were investigated at three locations in the province: Wollaston Lake area, Fond du Lac area and Clearwater River area. Several waterbodies within each of these locations were examined. A mark-recapture experiment was carried out to estimate grayling populations. The majority of grayling were captured by angling, using barbless hooks and flies. Estimated angling mortality (short-term) was 1.9%.

Examination of size composition of grayling at different locations in northern Saskatchewan revealed that variations occur among the populations, even within the same stream system. On the Umpherville River, grayling captured at the second set of rapids were smaller than those captured at the less accessible third set of rapids. A similar situation occurred on the Fond du Lac at the outlet of Black Lake. Grayling were smallest at Grayling Island, the site where most of the fishing occurs.

Age structure, like size, decreases in response to exploitation. A change in age composition of grayling towards younger fish has occurred in the Fond du Lac over the last few decades. In 1955, fish 7 - 10 years of age were captured, whereas in 1973-74, the majority of fish were 2 - 7 years and no fish older than 7 years of age were recorded. In the present survey, no fish older than 6 years of age were caught, and most fish were aged 2 - 5 years.

Rapid growth, early maturity and a short life span appear to be characteristic of the species. During the survey, the oldest fish captured was 9 years of age, as determined from scale samples. Maturity of grayling in Saskatchewan occurs at 3 - 4 years of age, when they reach a minimum size of 28 cm. Average fork length of spawning fish was 35.9 cm for females and 34.0 cm for males. Examination of grayling gonads in spring indicated that some females contained immature eggs, suggesting that grayling in Saskatchewan may not spawn every year.

Grayling reproduction in Saskatchewan occurs between mid-May and mid-June. Grayling in spawning condition were captured in Collins Creek and

Umpherville River from May 21 - 26, 1988. Possible cues that may initiate grayling spawning are day length, threshold temperature (≈4°C), and arrival of spring and subsequent break-up in headwater lakes. Spawning occurred in areas where water depths were less than 2 m, the substrate was gravel, rubble and boulder, and the water current was slow to moderate. The observation of juvenile grayling in amongst boulders along an island on Wollaston Lake far from any tributaries indicates that spawning can also occur in lakes.

Juvenile grayling eat a majority of chironomids in early summer, followed by a shift to a larger food item, caddisfly larvae, by August. Stream-dwelling adult grayling rely on aquatic insects for their diet, including caddisflies, mayflies and aquatic bugs. Grayling in Wollaston Lake ingest mainly terrestrial organisms such as wasps, grasshoppers, beetles and spiders that land on the water surface.

Tag-recapture data collected during the survey indicate that grayling remain relatively sedentary throughout the summer months. The majority of the 147 recaptured grayling were caught at their tagging site. Only 6 grayling, tagged in the Umpherville River, were recaptured away from the catch and release area. Maximum distance moved was 1.7 km. Some evidence suggests that grayling undergo migrations to overwintering areas. The capture of tagged grayling over a year after marking at the tagging site indicates that grayling may return to their home stream to spawn.

Population estimates derived from the mark-recapture experiment ranged from 91 grayling at a small tributary to Close Lake to almost 25 000 grayling at Bigstone Rapids on the Cochrane River. Estimates for Umpherville

River and Collins Creek, two road accessible sites, were 225 and 726 grayling respectively. Grayling populations at Grayling Island (5024) and Elizabeth Falls (3844) on the Fond du Lac were somewhat less than numbers estimated in 1974.

Numbers of grayling caught by anglers varied from a minimum of 1.1 fish/angler and 0.2 fish/angler-hr on the Geikie River to a maximum of 25.7/angler and 6.1/angler-hr on the Waterfound River during the summers of 1987 and 1988. Success rates tended to be higher at the more remote fly-in locations (Waterfound River, Fond du Lac) than at road accessible sites (Umpherville River, Geikie River).

Average size, growth and maturation of the grayling in northern Saskatchewan compare favourably with other North American populations. Because of lack of previous data, it is difficult to determine changes in abundance of grayling in Saskatchewan, but evidence collected indicates that characteristics of the populations have changed. Exploitation has altered population structures in several locations and has also depleted stocks at some of the more easily accessible sites.

Management recommendations should consider the following possibilities:

1. Lower the angling limit to 2 fish per day (4 in possession) with no more than one fish to exceed 30 cm in fork length.

2. Implement the mandatory use of barbless hooks and flies for grayling fishing.

3. Re-evaluate the status of grayling populations in northern Saskatchewan in 5 - 10 years to assess the management strategy that has been implemented.

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Bill Musker prepared and analyzed the grayling ageing materials, and Carol Schurr prepared the manuscript.

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1. GENERAL INTRODUCTION

1.1 BACKGROUND

Arctic Grayling (*Thymallus arcticus*) are distributed in the northern third of Saskatchewan as far south as the 56th parallel (Fig. 1) although they have been successfully stocked in waterbodies further south. Natural habitat of grayling in Saskatchewan consists of northern rivers and rocky creeks where swift flowing waters and rapids abound, and along the rocky shorelines and islands of clear, northern lakes.

In northern Saskatchewan, grayling are utilized both by anglers and by domestic fishermen. Although not usually sought after as a food fish, grayling are highly prized by anglers because of their sporting catch and unique appearance. Grayling are one of the few species native to Saskatchewan that can readily be taken by flyfishing. Historically, Indians and Eskimos took large numbers of grayling, primarily as food for their dogs and to a lesser extent, for themselves (Scott and Crossman 1973). Natives on the Fond du Lac still net grayling in the spring when the fish congregate on their spawning grounds. Commercial fishermen take grayling only incidentally as their nets are not normally set in grayling waters.

Because grayling have a limited distribution, tending to occur in isolated 'pockets' and because they are easy to capture, this species is vulnerable to being overfished. Up to the present time,

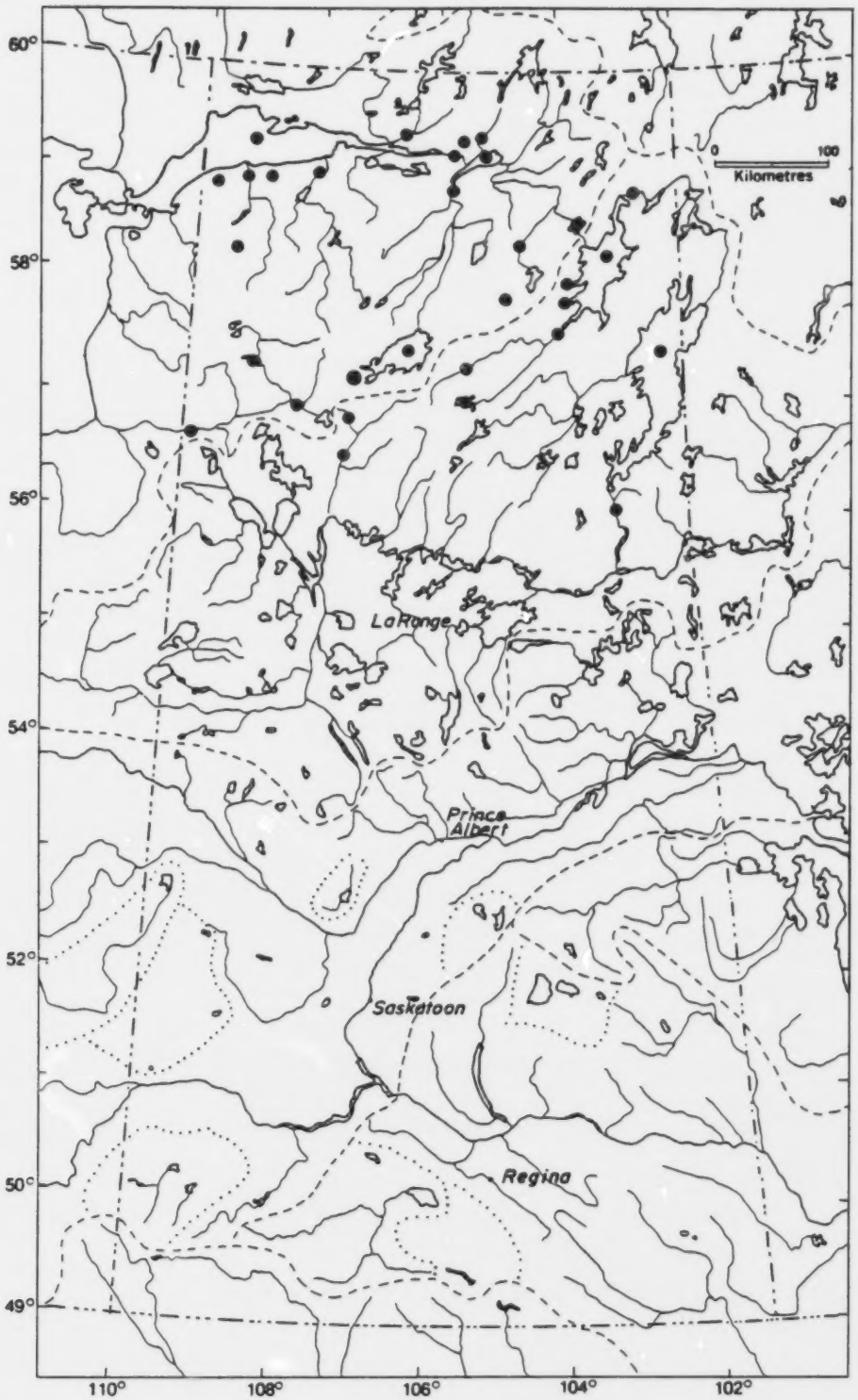

Fig. 1 Distribution of Arctic grayling in Saskatchewan (from Atton and Merkowsky 1983).

little information was available on grayling populations in Saskatchewan. Rawson (1950) published a paper on grayling in northern Saskatchewan that dealt mainly with the food habits of the species. An environmental impact assessment on the proposed hydroelectric project at Elizabeth Falls (Envirocon 1974) and a graduate thesis (Kratt 1977) provide some information on grayling populations in the Fond du Lac.

Over the last few years, outfitters have become concerned about the status of grayling in Saskatchewan. A survey distributed to outfitters in northern Saskatchewan in July, 1986 revealed that the majority of respondents favoured a reduced limit. The present limit for grayling is 5 fish per day (or 10 in possession) with no more than one fish exceeding 1 kg.

As a result of the concern for this native game fish, a two year study of the Arctic grayling in northern Saskatchewan was begun in May, 1987 by the Saskatchewan Fisheries Laboratory in Saskatoon. Objectives of the study were to investigate the biology of the grayling and to assess population levels before introducing a new management strategy.

1.2 DESCRIPTION OF THE STUDY AREA

Grayling were examined at three major areas in the province - Wollaston Lake area, Fond du Lac area and the Clearwater River area. All three areas lie on the Precambrian shield, a region typified by rugged granite boulders and numerous cliffs. The Clearwater River area, lying adjacent to the Athabasca Plains region, is distinguished by sand plains, moraine, sandy till and bedrock. The climate in the study area is a harsh, continental climate typical of northern Saskatchewan with relatively short, warm summers and long, cold winters. Lying in the northern coniferous forest region of the province, the area is vegetated by aspen and white spruce. Black spruce and tamarack grow in the low-lying areas and jack pine is dominant on sandy soils (Richards and Fung 1969).

The Wollaston Lake area lies in the far northeast section of the province (Fig. 2). Access to the area is limited to Highway 905, which runs north from the Southend junction and ends at Eldor Mines, located on the west side of Wollaston Lake. Points North, a freight station that serves as a shipping depot for northern Saskatchewan, can be reached from a 30 km access road off Highway 905. Wollaston Post, a community of approximately 200 people, is located on the east side of Wollaston Lake and is accessible by air, or by barge in the ice-free season. Four outfitting camps are located on Wollaston Lake, three of which are accessible from Highway 905. Fly-in fishing camps also operate on the Wheeler River, Keefe Lake, Russell Lake and Close Lake,

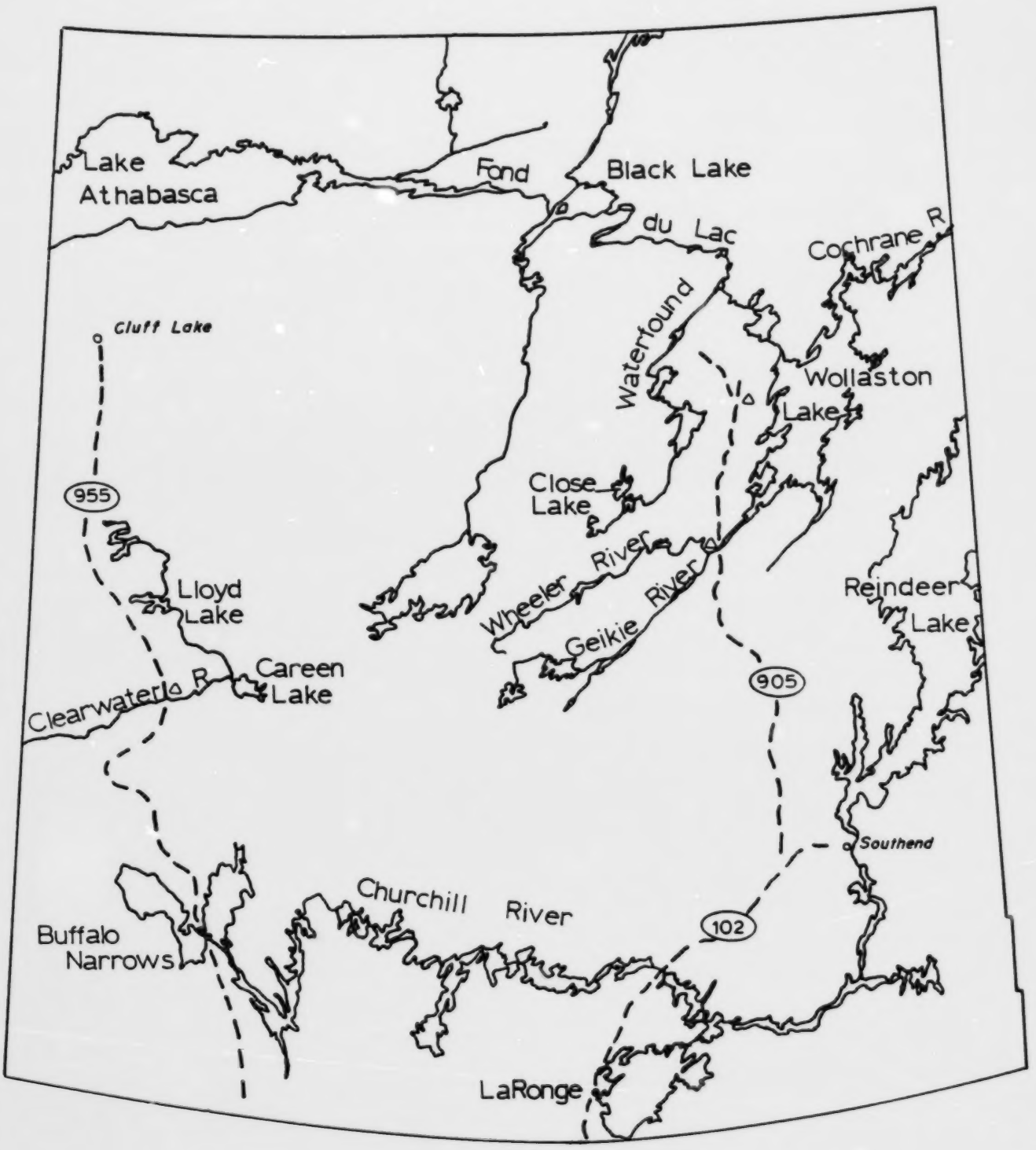

Fig. 2 Map of northern Saskatchewan.
Δ – Provincial campground.

and day-use camps are run at Bigstone Rapids on the Cochrane River and on the Waterfound River. Provincial campgrounds at the highway crossings of the Geikie River and Umpherville River provide accommodation for summer anglers.

The Fond du Lac area is situated in the extreme north-central section of Saskatchewan (Fig. 2). Access to the region is by air alone. Two major settlements are located in the area, Stony Rapids, situated upstream from Lake Athabasca on the Fond du Lac River, and Black Lake, located near the Fond du Lac outlet of Black Lake. Two fly-in fishing camps operate at the Fond du Lac outlet of Black Lake. A 23 km road connects Stony Rapids, Black Lake and the two fishing camps. Several other fishing lodges are located on the Fond du Lac downstream of Black Lake outlet and in the Lake Athabasca area.

The Clearwater River area is situated in the northwest section of the province (Fig. 2). Access to the area is by Highway 955 north of La Loche. The Clearwater River area has just recently been made into a wilderness provincial park. A provincial campground, situated at the highway crossing of the river, serves to accommodate the canoeists and fishermen visiting the park. La Loche, a community of nearly 2 000 people, is the nearest center and is located 85 km south of the park. Fly-in fishing camps operate at Lloyd Lake and Careen Lake. Clearwater Raft Tours offer white water rafting expeditions at several sites along the river.

2. METHODOLOGY

2.1 SAMPLING LOCATIONS

Grayling populations were investigated at three main areas in the province (Fig. 2). Several waterbodies within each of the areas were examined:

Location	Date Examined
1. Wollaston Lake area (Fig. 3):	
1. Wollaston Lake	June-Aug.,1987,1988
2. Collins Creek	May-Aug.,1987,1988
3. Umpherville River	May-Aug.,1987,1988
4. Bigstone Rapids, Cochrane River	June 4, 1987
5. Waterfound River	June 18, 19, 1988
6. Geikie River	June-Aug.,1987,1988
7. Close Lake - Yalowega River outlet & Jackfish Bay Creek	July 8-12, 1988
8. Wheeler River - Moore Lakes vicinity	July 15-19, 1988
2. Fond du Lac area (Fig. 4):	
1. Grayling Island	June 29-July 8, 1987
2. Elizabeth Falls	June 29-July 8, 1987
3. Middle Lake inlet	June 29-July 8, 1987

4. Chipman River — July 2, 1987
5. Lefty Falls - Grease River — July 3, 1987
6. Woodcock Rapids — July 6, 1987

3. Clearwater River area (Fig. 5):

1. Careen Lake outlet — July 23-27, 1987
2. Lloyd Lake outlet — July 28-29, 1987
3. Highway 955 crossing — Aug. 4-8, 1988

Individual sites within each area were selected based upon ease of access, transportation costs, and presence of a campground or outfitter so that some method of facilitating tag returns was available. Usually 5 - 10 days were spent sampling grayling at each of the locations. Several weeks were spent at the Wollaston Lake area in both 1987 and 1988. Appendix 1 gives a detailed account of the field schedule, and description of individual sites sampled.

2.2 PHYSICO-CHEMICAL FEATURES

Surface water samples for chemical analyses were collected weekly in 2-L plastic bottles and filtered immediately, using a hand-operated vacuum pump and Gelman Type A-E glass fiber filters. The samples were then kept under refrigeration until they could be analyzed. pH was measured in the field at the same time that the water samples were collected, using a Fisher Model 640 Accumet Mini pH/mV meter. pH was remeasured in the lab with a Fisher Accumet Model 230 pH meter.

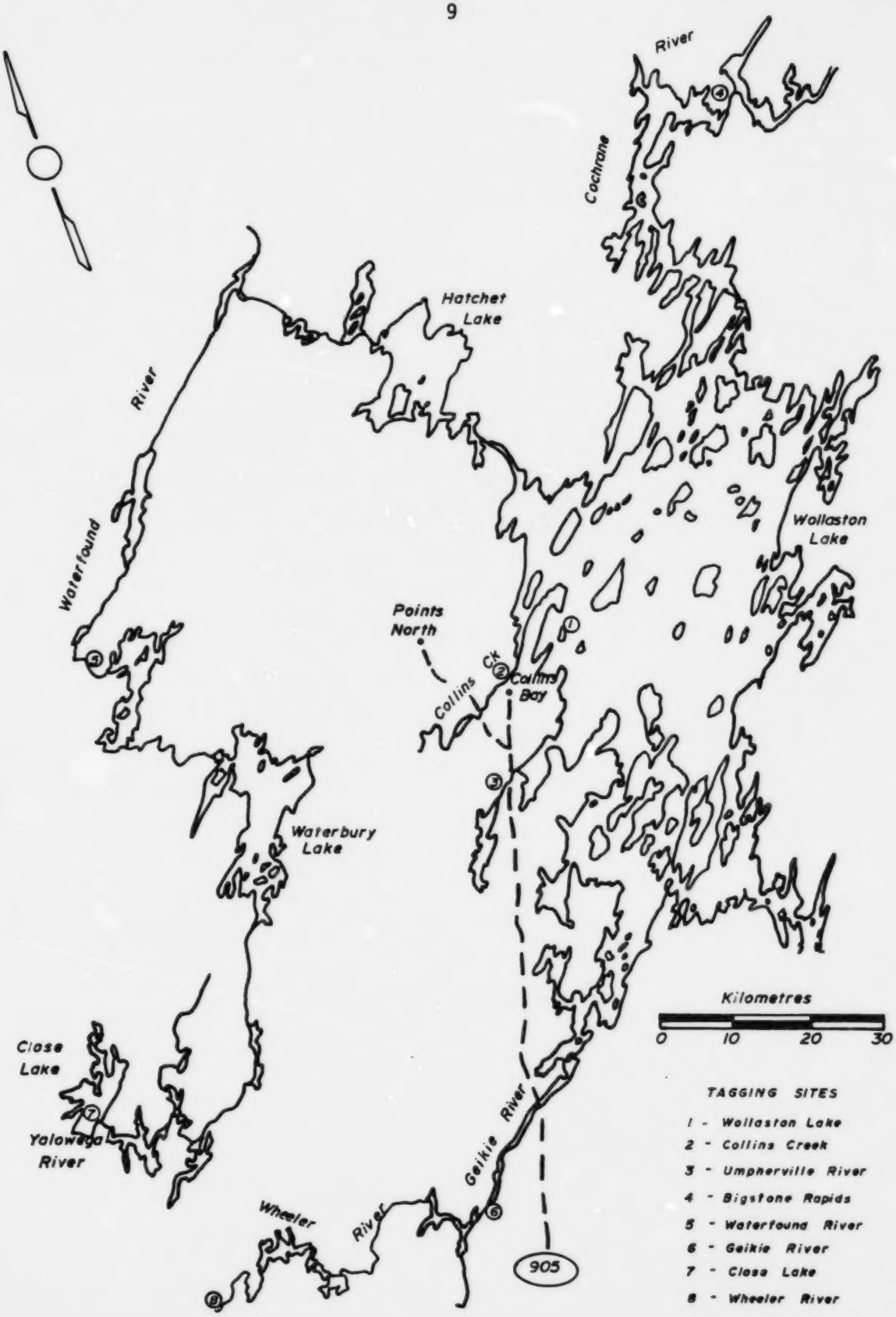

Fig. 3 Grayling tagging locations in the Wollaston Lake area.

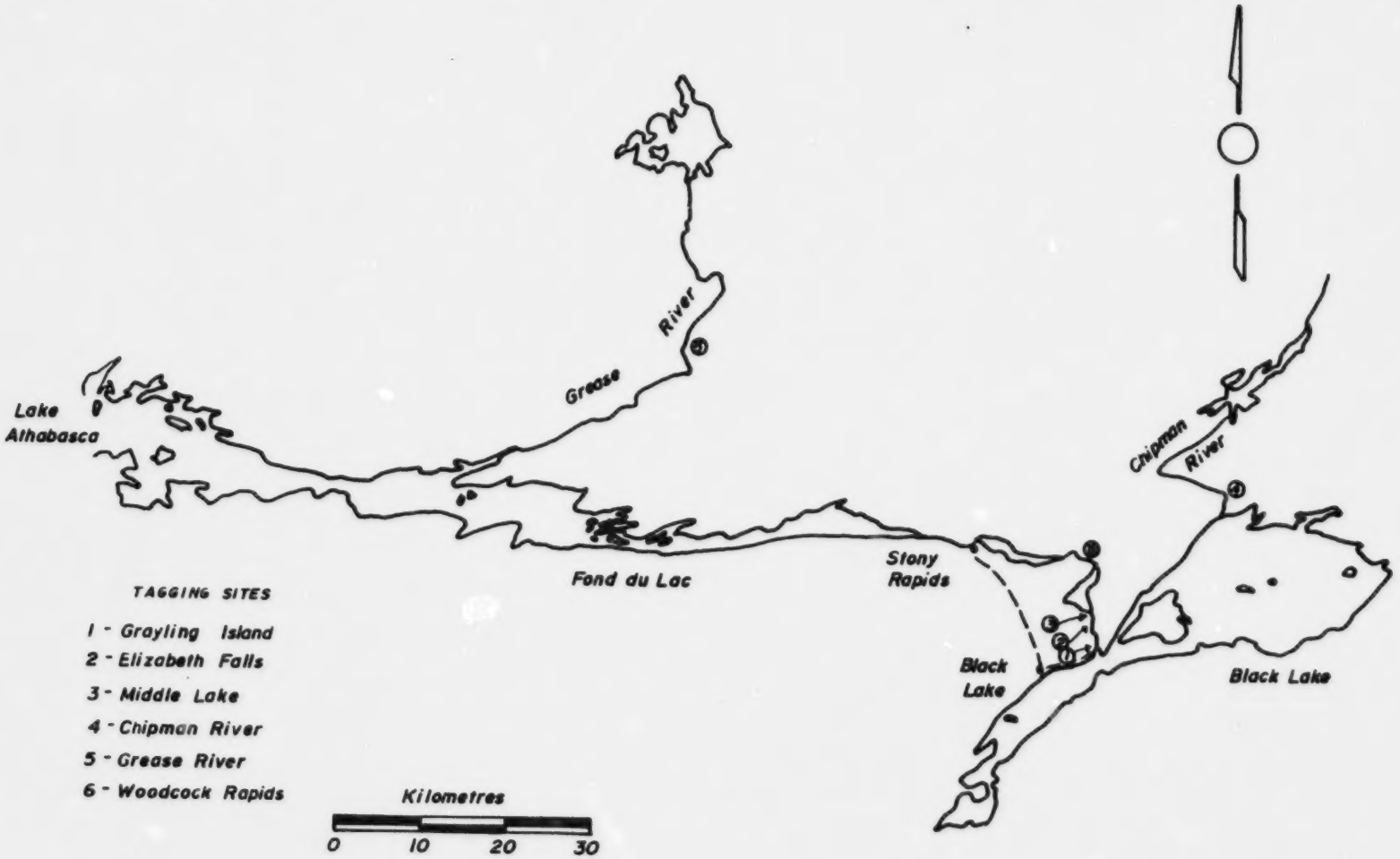

Fig. 4 Grayling tagging locations in the Fond du Lac area.

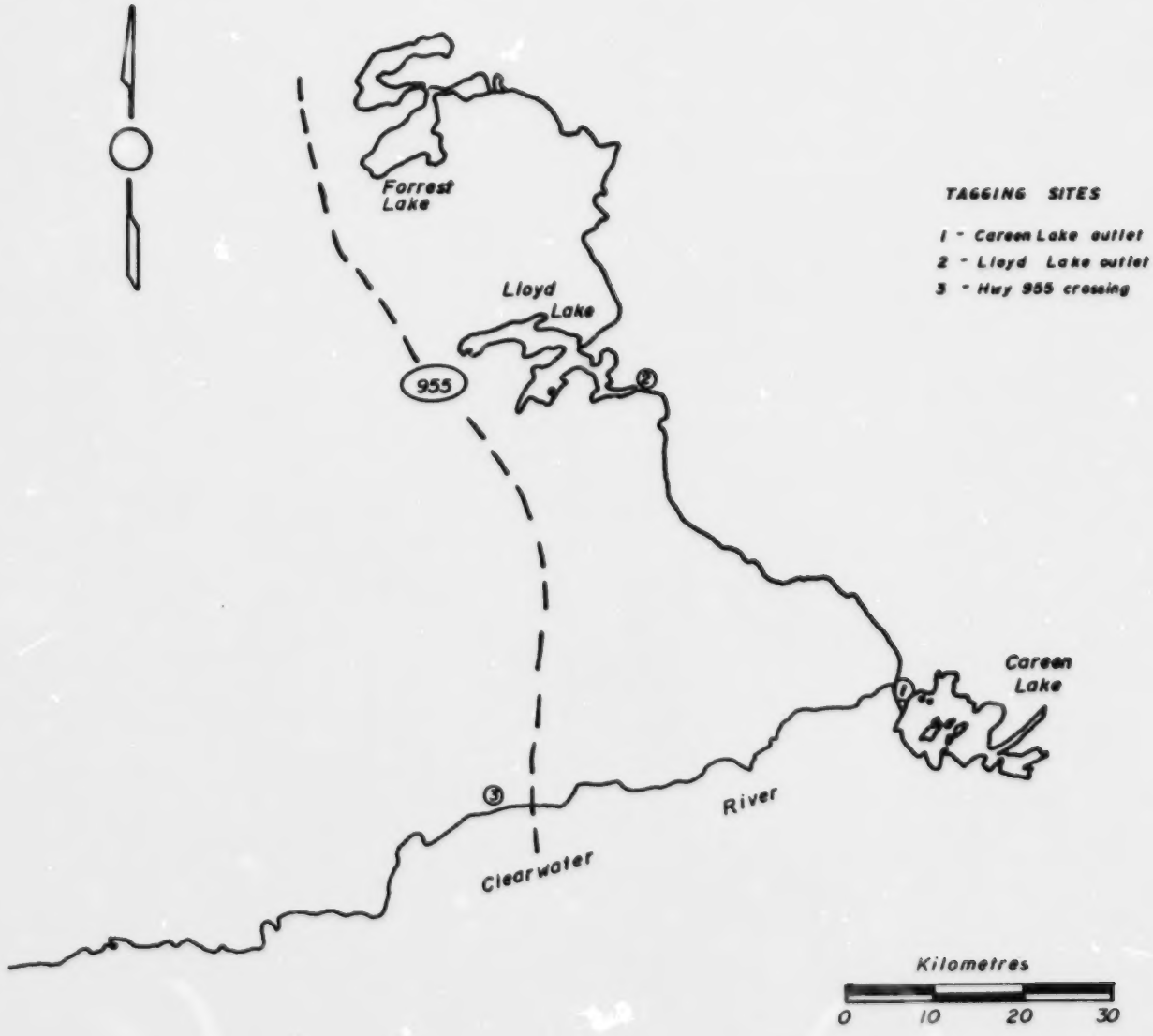

Fig. 5 Grayling tagging locations in the Clearwater River area.

Temperature was measured daily at Collins Creek in the spring of 1988, using a minimum-maximum thermometer.

Total alkalinity was measured by determining the inflection point using potentiometric titration with standard hydrochloric acid (APHA 1971).

Calcium was determined by EDTA titration using murexide as the indicator (APHA 1971). Hardness levels were determined by using Eriochrome Black-T as the indicator (EPA 1979). Magnesium was calculated from values of hardness and calcium (Environment Canada 1974); Mg ($mg.L^{-1}$) = 12.16 (total hardness as $CaCO_2$ x 0.01998 - Ca x 0.0499).

Chloride was measured titrimetrically, using mercuric nitrate in the presence of mixed diphenylcarbazone - bromophenol blue indicator (EPA 1979).

Total dissolved solids (TDS) were measured as the amount of filtrable residue of a 100 mL water sample dried at 110°C (APHA 1971).

Stream substrate type was calculated by measuring 3 m cross-sections of the stream channel at 30.5 cm intervals, following the method of Platt et al. (1983).

Stream gradients were determined by measuring the stream length between contour intervals on 1:50 000 topographical maps.

2.3 INVERTEBRATES

Invertebrate sampling was carried out to collect organisms that would be encountered in grayling stomachs and thus help in the identification of stomach contents. As well, there was a possibility that invertebrate sampling gear would collect grayling eggs and fry. Invertebrates were sampled in northern Saskatchewan waterbodies, using a variety of methods.

In 1987, drift nets were used to sample invertebrate fauna. Drift nets are long and funnel-shaped with rectangular openings. The nets are anchored in the stream using two poles, and organisms carried by the current are collected in the net. All drift nets were left in the stream for a 1/2 hr period during the day to capture organisms, and samples collected were preserved in 70% alcohol for future identification. These nets were not used in 1988, as analyses of 1987 samples indicated that this method was not efficient in capturing organisms.

A Surber sampler, consisting of a 930 cm^2 brass frame with a net attached at right angles was used to collect invertebrate fauna in areas less than 1 m deep. The frame is placed over the substrate and the rocks and stones within the frame are scoured by hand. Organisms dislodged are swept into the net by the current from which they are removed and preserved in 70% alcohol for identification in the lab. Surber samples were taken in both 1987 and 1988 on a weekly basis.

Sweep nets were also used to collect invertebrate fauna. These nets are attached to a D-shaped frame and a long handle. The sampler walks backward into the current with the net held in front and against the bottom, stirring up the substrate with his feet. Organisms dislodged are swept into the net by the current from which they are removed and preserved in 70% alcohol. Sweep net sampling was done for 5 minute intervals so results would be comparable. Sweep net samples were collected in both 1987 and 1988 on a weekly basis.

2.4 CAPTURE AND TAGGING OF GRAYLING

Adult grayling were captured using hoopnets, gillnets and by angling. Hoopnets were installed at two locations in Collins Creek, a tributary to Wollaston Lake, in the spring of both 1987 and 1988. In 1987, a hoopnet was set up at the pumphouse in Collins Creek on May 21. The second net was set downstream of the first net on May 23, adjacent to the borrow pit. In 1988, a hoopnet was set up at the pumphouse on May 17. A second net was set up downstream of the pumphouse adjacent to the airport on May 17. The nets were removed on June 8 in 1987, and on May 26 in 1988.

Gillnets, consisting of 68.6 m lengths of nylon mesh, (22.9 m each of 3.8, 5.1, and 7.6 cm stretched mesh) were set periodically at the base of rapids and in some of the lakes to capture grayling. The nets were usually checked every 40 - 45 minutes so that any grayling captured could be removed. Other fish were released. The

nets were then left overnight and removed the following day. Dates and locations of gillnet sets are listed in Appendix 1.

Grayling were also captured by angling. Both fly fishing and spincasting gear were used. A variety of lures was employed, including spinners (Panther-Martin silver spinners), spoons (Froggers and Potato Bugs) and flies (black gnat, mosquito, mayfly, caddisfly, stonefly, woolly worm, royal coachman, irresistible, leech, dragonfly and brown hackle fly). All hooks and flies were made barbless by pinching the barbs with pliers.

Grayling captured were placed in plastic fish tubs filled with water. Tagging was undertaken after several grayling were accumulated in the tubs, or within half an hour of capture. On hot days, the water in the tubs was changed frequently to ensure an adequate oxygen supply for the fish. Grayling were observed in the tubs for approximately half an hour to be certain that they were healthy enough to withstand tagging. All healthy grayling were measured (fork length), sex was noted if possible, and 1-2 scales were taken from each fish for determination of age. In 1988, grayling were also weighed by placing them in a tared trough. The grayling were then tagged on the gillcover with a Monel metal strap tag (#3) that was attached by using pliers. Each tag was inscribed with the initials "SPRC" and a unique number so that fish could be individually identified. Tagged grayling were released at the same location at which they were caught. In May 1988, a holding pen was installed in Collins Creek at the pumphouse location.

Equal numbers of tagged and untagged fish were put into the pen for a week to determine tag retention and any injuries due to tagging.

A $2 reward was offered to anglers who reported the capture of a tagged grayling in 1987 and 1988. A grayling crest was given as a reward for tag returns after 1988. Outfitters and local resource officers kept records of grayling caught by anglers in the vicinity, and collected information on tagged fish captures. Self-registering survey stations were installed at Elizabeth Falls, and at the campgrounds on the Umpherville, Geikie and Clearwater Rivers so that local residents and campers could report on their grayling fishing trips.

Dead grayling (from angling injuries or captured in the gillnets) were weighed and measured, sex and state of maturity were noted and stomachs were preserved in 10% formalin for analyses in the lab. Pectoral fin rays, otoliths and scales were collected for comparison of ages derived with various ageing techniques. Techniques used for collecting and preparing ageing material are described by Musker (1985).

Juvenile grayling were captured with a seine net, lift net and fry net. Seine nets were pulled along sandy beaches in some of the northern lakes. A lift net was used in quiet, back-water areas of the streams. A lift net is an umbrella-shaped net that is lowered to the bottom substrate by a rope. The net is simply pulled up when a fish is observed swimming over it. Fry nets, which are basically a small mesh gillnet (1.9 cm mesh) were set along the shores of northern lakes and

streams. They were set by wading out into waters approximately 1 - 1.5 m deep. These nets could be used in waters of moderate current, especially if one end was tied to a tree or rock on shore.

Grayling fry were captured in some of the invertebrate sampling gear, and by using a small mesh dipnet. Grayling juvenile and fry were preserved in 10% formalin. Length and weight measurements and identification of stomach contents were done in the lab.

3. RESULTS

3.1 FISH HABITAT

3.1.1 Physico-Chemical Features

In Saskatchewan, grayling occur naturally only in the Arctic and Churchill drainage basins (Atton and Merkowsky 1983). The Fond du Lac River, Close Lake and Clearwater River lie in the Arctic drainage basin. Although Wollaston Lake has outflows into both the Arctic drainage via the Fond du Lac, and the Churchill drainage via the Cochrane River, Reindeer Lake and Reindeer River, it is considered to lie within the Churchill basin since the major outflow is the Cochrane River.

The lakes and rivers examined are characterized by waters low in alkalinity, hardness, total dissolved solids and pH similar to other waterbodies lying on the Canadian Shield. Total alkalinity ranged from 5.3 $mg.L^{-1}$ in Collins Creek in May, 1988 to 20.2 $mg.L^{-1}$ in Collins

Creek in June, 1987 (Appendix 2). Total dissolved solids varied from 7 $mg.L^{-1}$ in the Waterfound River to 64 $mg.L^{-1}$ in the Umpherville River in May, 1988. pH values of all waters were between 6.89 and 7.42 with the exception of a reading taken in the Umpherville River which measured 8.42. Calcium and chloride levels were generally less than 10 $mg.L^{-1}$ in all the waterbodies. Levels of total hardness and magnesium could not be detected.

Channel gradients, the drop in water surface elevation per unit length of channel, were determined for several streams in the study area (Table 1). Average stream width varied from 35 m in Collins Creek to 230 m in the Geikie River. Gradients ranged from 1.58 m/km on the Clearwater River to 17.10 m/km at Woodcock Rapids on the Fond du Lac.

The composition of the channel substrate at the second set of rapids on the Umpherville River was determined on August 19, 1987 when low water levels caused exposure of the bottom materials. Two 3 m cross-sections of the stream channel were examined, following the method of Platt et al. (1983). Materials assigned to the major sediment class (boulder, gravel, rubble or sediment) were given for each 30.5 cm division (Appendix 3). Based on this method of classification, the substrate of the Umpherville River is composed of 25% large boulder, 20% small boulder, 50% rubble and 5% gravel.

Table 1. Stream gradients (m/km) of waterbodies examined for grayling in 1987 and 1988.

River	Altitude m	Average stream width, m	Distance, km	Gradient, m/km
Umpherville R. - between Ahenakew & Wollaston Lakes	410	70	4.1	2.44
Wheeler R. - between Russell and Keefe Lakes	470	145	9.0	
	480		1.6	3.68
Clearwater R. - Warner Rapids to Mackie Rapids	400			
	410	125	5.0	1.58
	420		8.6	
Geikie R. - between Wollaston Lake and 2nd rapids	400	230	5.1	1.96
	410			
Fond du Lac - Elizabeth Falls	250			
	260	115	0.6	
	270		2.6	10.26
Woodcock Rapids	220			
	230		0.4	
	240		1.1	17.10
Collins Creek - between Kewen L and Wollaston L.	400			
	410	35	1.1	10.10
	420		0.9	

3.1.2 Biological Properties (Food Organisms)

Data on organisms collected in drift nets, sweep nets and Surber samples are presented in Appendices 4-8. Dipterans, especially chironomids, were predominant in the drift net samples. Mayflies (Ephemeroptera) and caddisflies (Trichoptera) dominated the sweep net samples. *Brachycentrus* (Brachycentridae) and *Lepidostoma* (Lepidostomatidae) were the most common caddisflies encountered while *Drunella* (Ephemerellidae) was the most common mayfly. The Surber samples were dominated by caddisflies and dipterans. In 1987, chironomids were the most common dipteran identified but in 1988, blackflies were dominant. Samples collected in late summer tended to contain more organisms than those collected in May and early June.

Although the various types of sampling gear used do not provide for quantitative analyses, average number of organisms per sample at each location in northern Saskatchewan has been given in Table 2 for comparison. Collins Creek had the highest density of organisms per sample. The major groups comprised caddisflies (44.1%) and dipterans (35.3%). The outlet of Careen Lake had the lowest number of organisms per sample, the majority of which was the Amphipod, *Hyalella* (37.9%). Amphipods were only found at Careen Lake and at the outlet of Lloyd Lake. Both of these locations are part of the Clearwater River system. Dipterans, mayflies, caddisflies and stoneflies (Plecoptera) were common in most samples collected. The absence or scarcity of certain types of organisms in some of the samples

Table 2. Average number of organisms collected per sample at various locations in northern Saskatchewan in 1987 and 1988.

	Collins Cr.		Umpherville R.		Geikie R.		Pond du Lac R.		Careen L.		Lloyd L.		Yalowega R.		Wheeler R.		Clearwater R.	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Insecta:																		
Coleoptera*	0.1	0.1	0.1	0.1	0.0	0.0	0.2	0.3	0.3	1.0	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Diptera	70.3	35.3	34.7	41.3	10.2	13.2	66.5	88.9	7.7	26.6	2.0	1.2	9.0	14.2	10.0	9.2	42.0	23.4
Ephemeroptera	27.4	13.8	18.3	21.8	22.1	28.7	2.0	2.7	2.7	9.3	4.0	2.5	4.5	7.1	11.0	10.1	25.0	13.9
Hemiptera	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hymenoptera	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lepidoptera	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Odonata	2.5	1.3	2.1	2.5	11.2	14.5	0.0	0.0	0.0	0.0	1.7	1.1	0.0	0.0	0.0	0.0	16.0	8.9
Plecoptera	6.1	3.1	6.7	8.0	1.5	1.9	0.3	0.4	0.0	0.0	3.3	2.1	0.5	0.8	5.0	4.6	8.5	4.7
Trichoptera	87.8	44.1	16.2	19.3	25.7	33.3	2.8	3.7	0.7	2.4	48.7	30.2	37.0	58.3	60.0	55.0	36.0	20.1
Amphipoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.0	37.9	9.3	5.8	0.0	0.0	0.0	0.0	0.0	0.0
Hirudinea	0.6	0.3	0.4	0.5	0.4	0.5	0.0	0.0	3.3	11.4	91.0	56.5	0.5	0.8	0.0	0.0	0.5	0.3
Nematoda	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oligochaeta	0.1	0.1	0.2	0.2	0.2	0.3	0.0	0.0	3.0	10.3	0.0	0.0	0.0	0.0	6.0	5.5	0.5	0.3
Gastropoda	1.4	0.7	0.1	0.1	0.4	0.5	1.8	2.4	0.3	1.0	0.7	0.4	2.5	3.9	3.0	2.8	0.0	0.0
Sphaeriidae	2.5	1.3	5.2	6.2	5.1	6.6	1.2	1.6	0.0	0.0	0.0	0.0	9.5	14.9	14.0	12.8	51.0	28.4
Total	199.0		84.1		77.1		74.8		29.0		161.0		63.5		109.0		179.5	
#Samples	19		19		13		6		3		3		2		1		2	

* Coleoptera - beetles; Diptera - flies; Ephemeroptera - mayflies; Hemiptera - aquatic bugs; Hymenoptera - wasps; Lepidoptera - aquatic caterpillars; Odonata - dragonflies and damselflies; Plecoptera - stoneflies; Trichoptera - caddisflies; Amphipoda - fresh-water shrimp; Hirudinea - leeches; Nematoda - roundworms; Oligochaetae - aquatic earthworms; Gastropoda - snails; Sphaeriidae - fingernail clams.

may be due to variations in sampling dates. Some locations were sampled on only one date whereas others (in the Wollaston Lake area) were sampled at several different times during the two years.

3.2 GENERAL LIFE HISTORY

3.2.1 Distribution

Grayling are found along the shores of larger northern lakes in Saskatchewan and in many of the tributary streams. In streams, the species occurs in isolated 'pockets', often at the base of waterfalls and rapids. In lakes, their habitat is usually along rocky shorelines, however in Close Lake, adult grayling were captured in gillnets set in the middle of the lake and juveniles were collected in seine nets pulled along sandy beaches. In the literature, grayling occurrences have been recorded for many waters in the Arctic and Churchill drainage basins (Atton and Merkowsky 1983). There are doubtless many more occurrences that have not been documented. Associated fish species include lake whitefish (*Coregonus clupeaformis*), longnose sucker (*Catostomus catostomus*), white sucker (*Catostomus commersoni*), northern pike (*Esox lucius*), nine-spine stickleback (*Pungitius pungitius*), slimy sculpin (*Cottus cognatus*), lake chub (*Couesius plumbeus*) and pearl dace (*Semotilus margarita*).

During the summer months, grayling have a long-term tendency to be sedentary. Fifteen grayling tagged in 1987 were recaptured in 1988 at their tagging site. With the exception of 6 fish tagged in the

Umpherville River, all grayling recaptures (147) occurred in the tagging vicinity. The extent and direction of travel of the 6 grayling in the Umpherville River that moved were:

Tagging site	Tagging date	Recapture site	Recapture Date	Distance travelled	Days at large
3rd rapids	21-5-88	2nd rapids	06-7-88	+ 1.7 km*	46
2nd rapids	07-6-87	3rd rapids	23-7-87	- 1.7 km	46
2nd rapids	21-5-87	3rd rapids	23-7-87	- 1.7 km	63
2nd rapids	21-5-87	3rd rapids	08-6-88	- 1.7 km	383
2nd rapids	07-6-87	1st rapids	15-7-87	+ 0.5 km	38
2nd rapids	21-5-87	1st rapids	16-7-87	+ 0.5 km	26

*downstream movement: +
upstream movement: -

Maximum distance travelled by grayling was 1.7 km. Three of the fish moved upstream, and three moved downstream. No conclusions can be made about the extent and direction of grayling movements.

It is unlikely that all grayling overwinter at the same place that they spend the summer. Several of the streams in the study area are small (eg. Collins Creek, Umpherville River), and low water levels in fall limit habitat available for the grayling during the winter months. Although the rapids do not freeze during winter, the development of frazil ice may make survival of the fish difficult. At Collins Creek and Umpherville River, it appears that grayling were overwintering elsewhere, either downstream in Wollaston Lake or upstream in a headwater lake. Field work in 1988 commenced on May 17. No grayling tagged in 1987 were recaptured during the first week of work in 1988, but on May 24, three grayling tagged in 1987 were caught at the

pumphouse on Collins Creek, the location at which they were tagged. After this date, recaptures were a frequent occurrence. Grayling were apparently moving into the pumphouse area from other locations. Similar results were obtained for the Umpherville River.

3.2.2 Body Proportions

Length-frequency distributions of graying captured in hoop nets, gillnets and by angling at various locations in northern Saskatchewan are indicated in Fig. 6 - 10. Grayling ranged in size from 8.1 to 46.0 cm. Average fork lengths of fish measured in the various waterbodies (Table 3) reveal that size differences occur among the populations, even among fish captured in the same stream but at different sites. For example, at the second set of rapids on the Umpherville River, grayling averaged 30.8 cm in fork length, whereas at the third rapids, average length was 36.3 cm. Similarly, average fork length of grayling caught in the Fond du Lac increased in a downstream direction, from 31.6 cm at Grayling Island to 37.9 cm at Middle Lake inlet. Most grayling at Jackfish Bay Creek were less than 30 cm in fork length whereas the majority of fish captured at Careen Lake were greater than 30 cm in length.

Average weights of fish, like fork lengths, varied with location, ranging from 172 g at Jackfish Bay Creek on Close Lake to 582 g for fish captured at the third set of rapids on the Umpherville

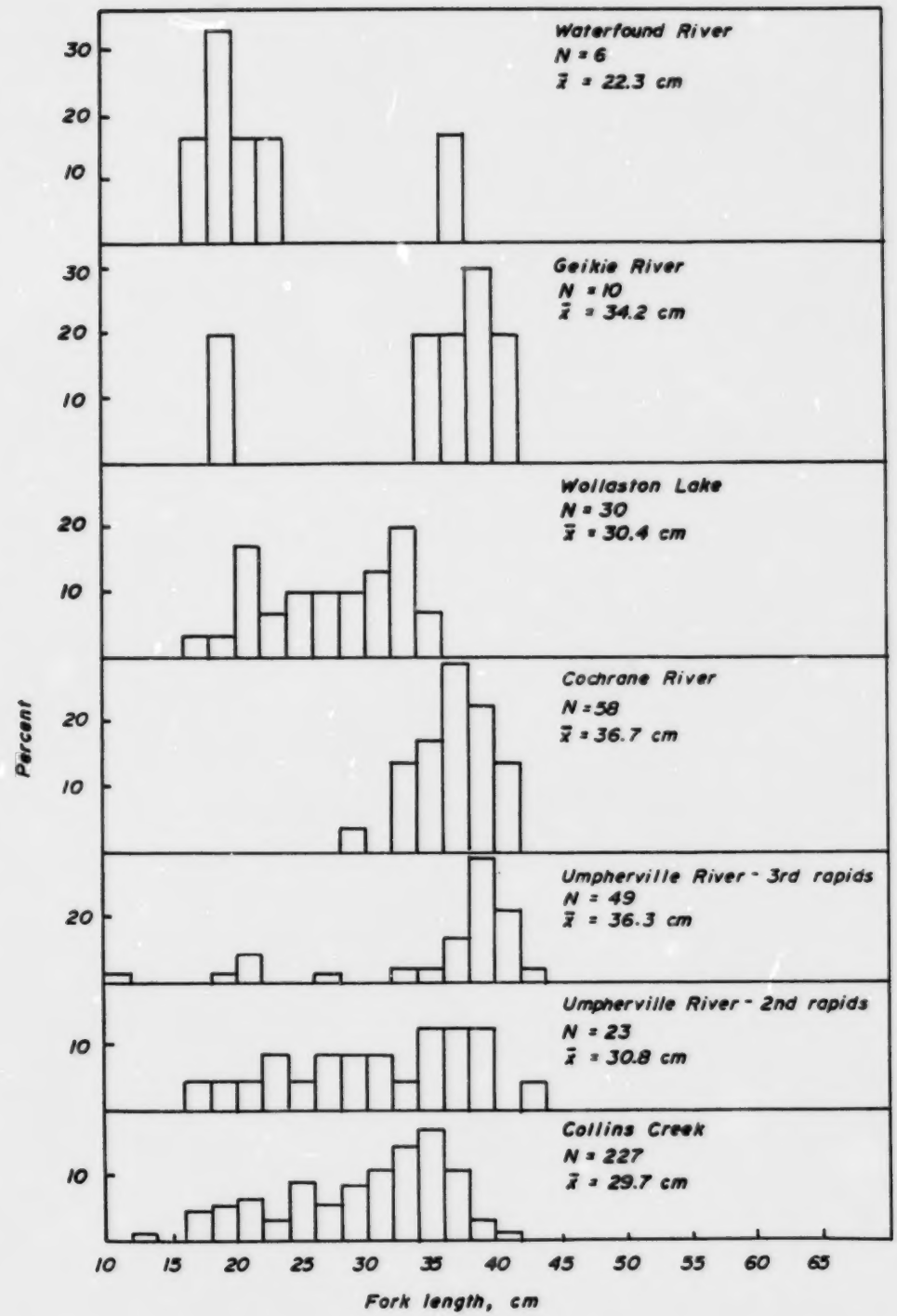

Fig. 6 Length-frequency distribution of grayling in six waterbodies in the Wollaston Lake area during 1987 and 1988. N = number of fish; $\bar{x}$ = mean fork length.

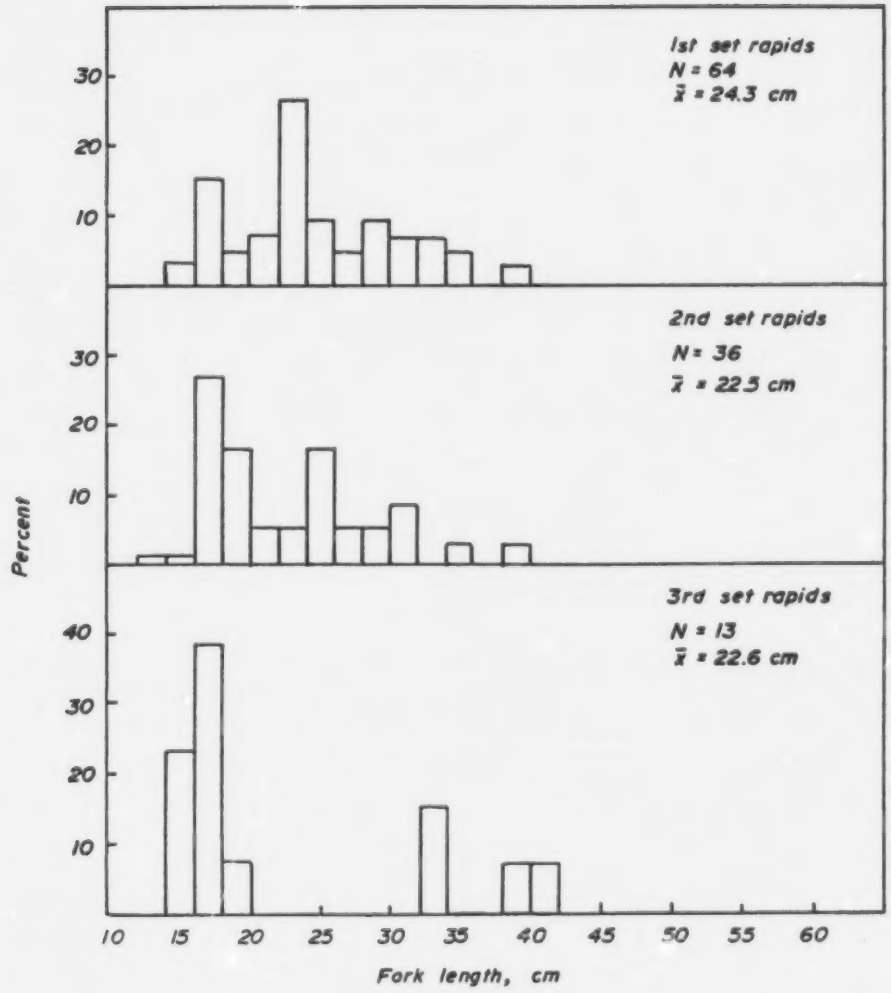

Fig. 7 Length-frequency distribution of grayling at three locations on the Wheeler River between Russell and Keefe Lakes in 1988. N = number of fish ; $\bar{x}$ = mean fork length.

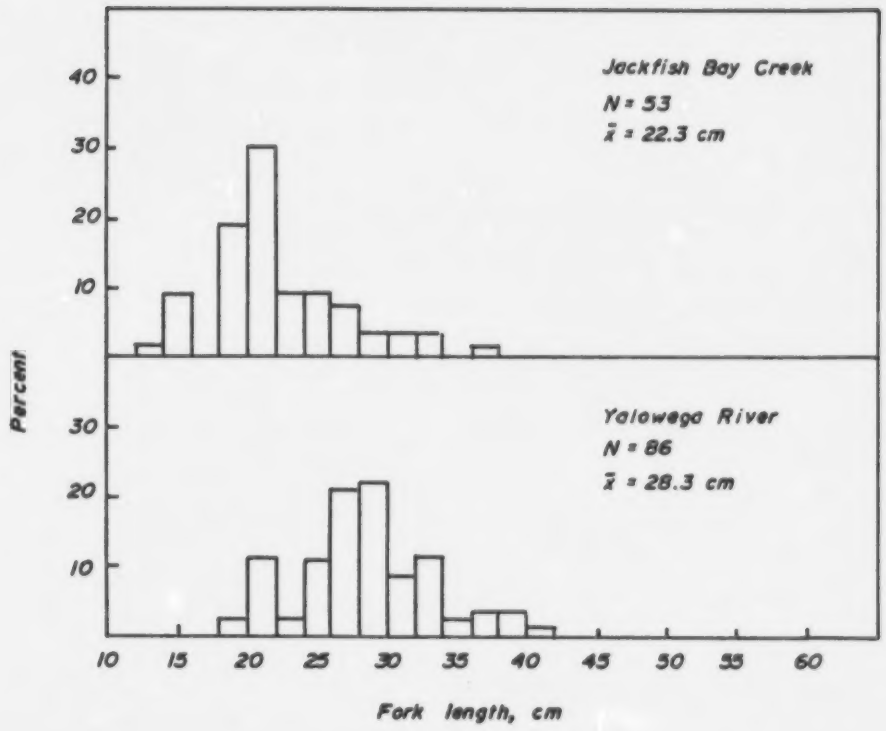

Fig. 8 Length-frequency distribution of grayling at two locations on Close Lake in 1988. N = number of fish ; $\bar{x}$ = mean fork length.

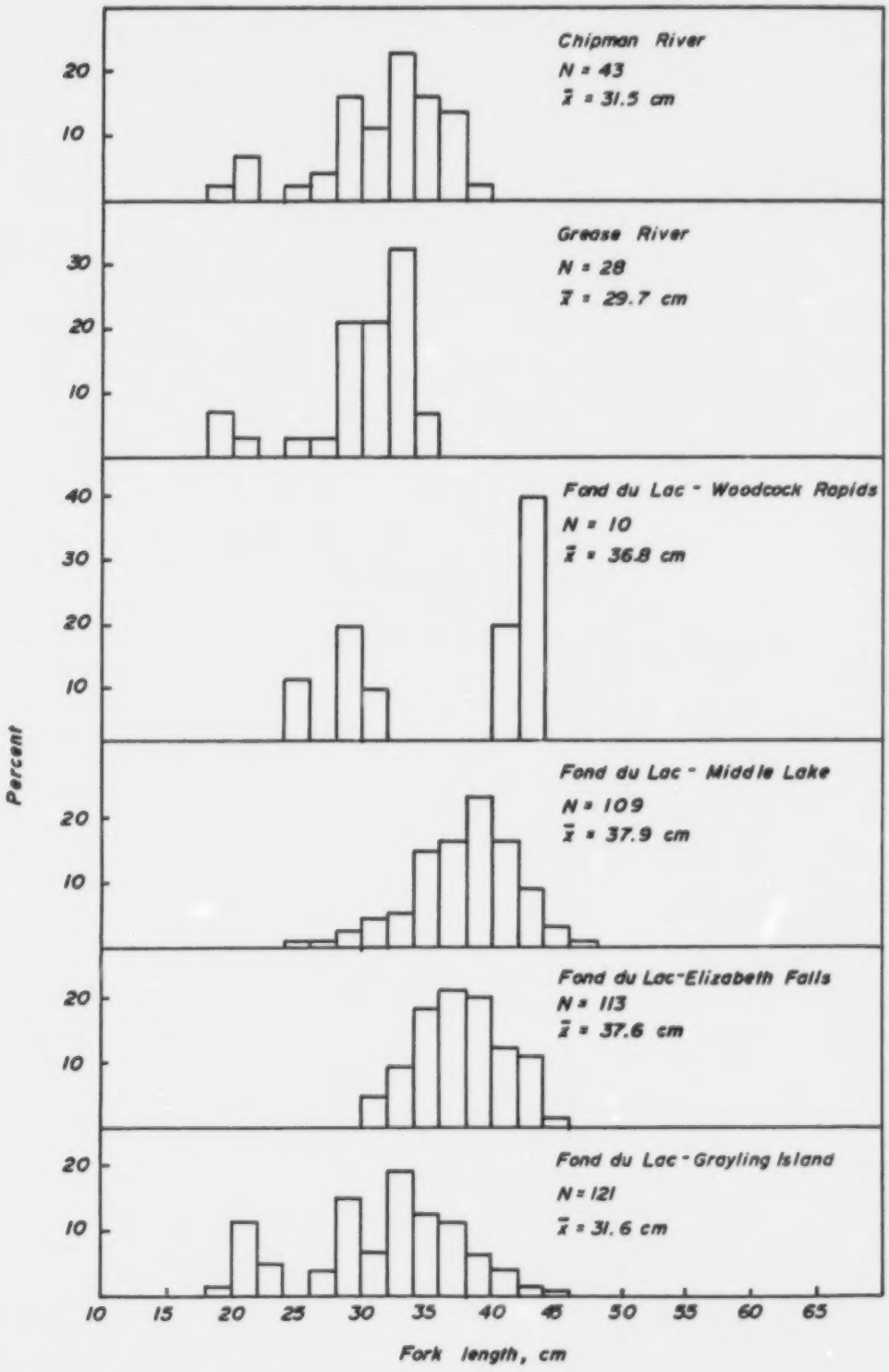

Fig. 9 Length - frequency distribution of grayling at six locations in the Fond du Lac area in 1987. N = number of fish ; x̄ = mean fork length.

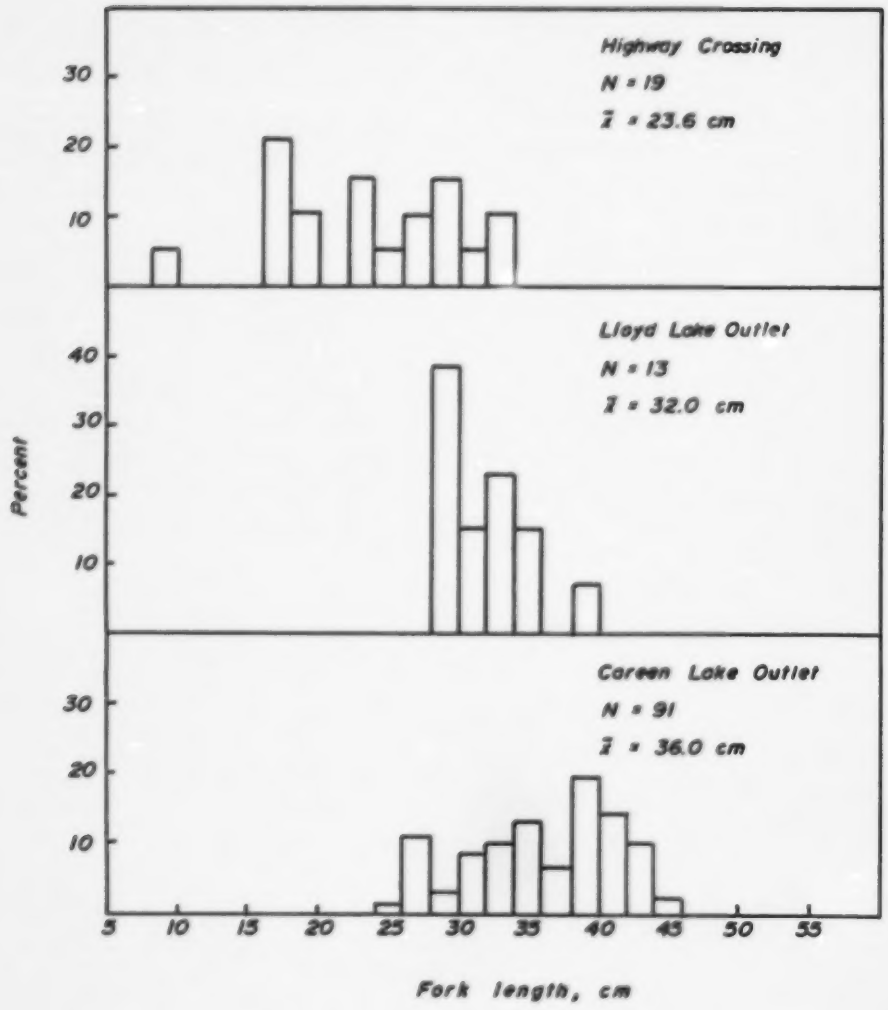

Fig. 10 Length - frequency distribution of grayling at three locations on the Clearwater River during 1987 and 1988. N = number of fish; $\bar{x}$ = mean fork length.

Table 3. Average fork lengths and weights, length-weight relationships and condition factors of grayling captured at various locations in northern Saskatchewan during 1987 - 1988.

Location	Average fork length,cm	Average weight,g*	Length-weight relationship	Condition factor,K
Wollaston Lake Area:				
Jackfish Bay Creek (Close Lake)	22.3	172	$W=0.009L^{3.125}$	1.33
Wheeler River - 2nd Rapids	22.5	219		
Wheeler River-1st Rapids	24.3	253	$W=0.027L^{2.819}$	1.57
Yalowega River (Close Lake)	28.3	332	$W=0.018L^{2.919}$	1.36
Collins Creek	29.7	394	$W=0.015L^{2.940}$	1.29
Wollaston Lake	30.4	361	$W=0.006L^{3.182}$	1.17
Umpherville River -2nd Rapids	30.8	246		
Umpherville River -3rd Rapids	36.3	582	$W=0.010L^{3.080}$	1.30
Cochrane River	36.7			
Fond du Lac Area:				
Grease River	29.7			
Chipman River	31.5			
Fond du Lac				
-Grayling Island	31.6			
-Elizabeth Falls	37.6			
-Middle Lake	37.9			
Clearwater River Area:				
Highway crossing	23.6	223	$W=0.009L^{3.145}$	1.39
Lloyd Lake outlet	32.0			
Careen Lake outlet	36.0			

*Since weights of most grayling captured in 1987 were not taken, average weight, length-weight relationship and condition factor could not be determined for several populations.

River (Table 3). Average weight of grayling caught at the third rapids on the Umpherville River was more than double that of fish captured at the second rapids.

Length-weight relationships for grayling caught in the Wollaston Lake area and Clearwater River are illustrated in Fig. 11 and 12. The resulting equations are given in Table 3, where W is weight in grams and L is fork length in centimetres. Because few weights were taken in 1987, length-weight relationships for grayling at several locations could not be determined.

Condition factor, an index of relative robustness of fish, was calculated based on the formula $K = (W \times L^{-3}) \times 10^5$ (Carlander 1969), where W is weight in kilograms and L is fork length in centimetres (Table 3). The condition of grayling varied from 1.17 for fish in Wollaston Lake to 1.57 in the Wheeler River. Condition factors of grayling varied significantly ($p<0.05$) when an analysis of variance to compare the means was applied. A t-test was used to determine which populations of grayling varied significantly from each other with respect to condition factor. Condition of grayling from Wollaston Lake was significantly lower ($p < 0.05$) than condition of all other populations studied. Relative robustness of fish from the Wheeler River was significantly better ($p < 0.05$) than fish from all other locations except Careen Lake. Grayling from the Yalowega River were significantly more robust ($p < 0.05$) than fish from Collins Creek.

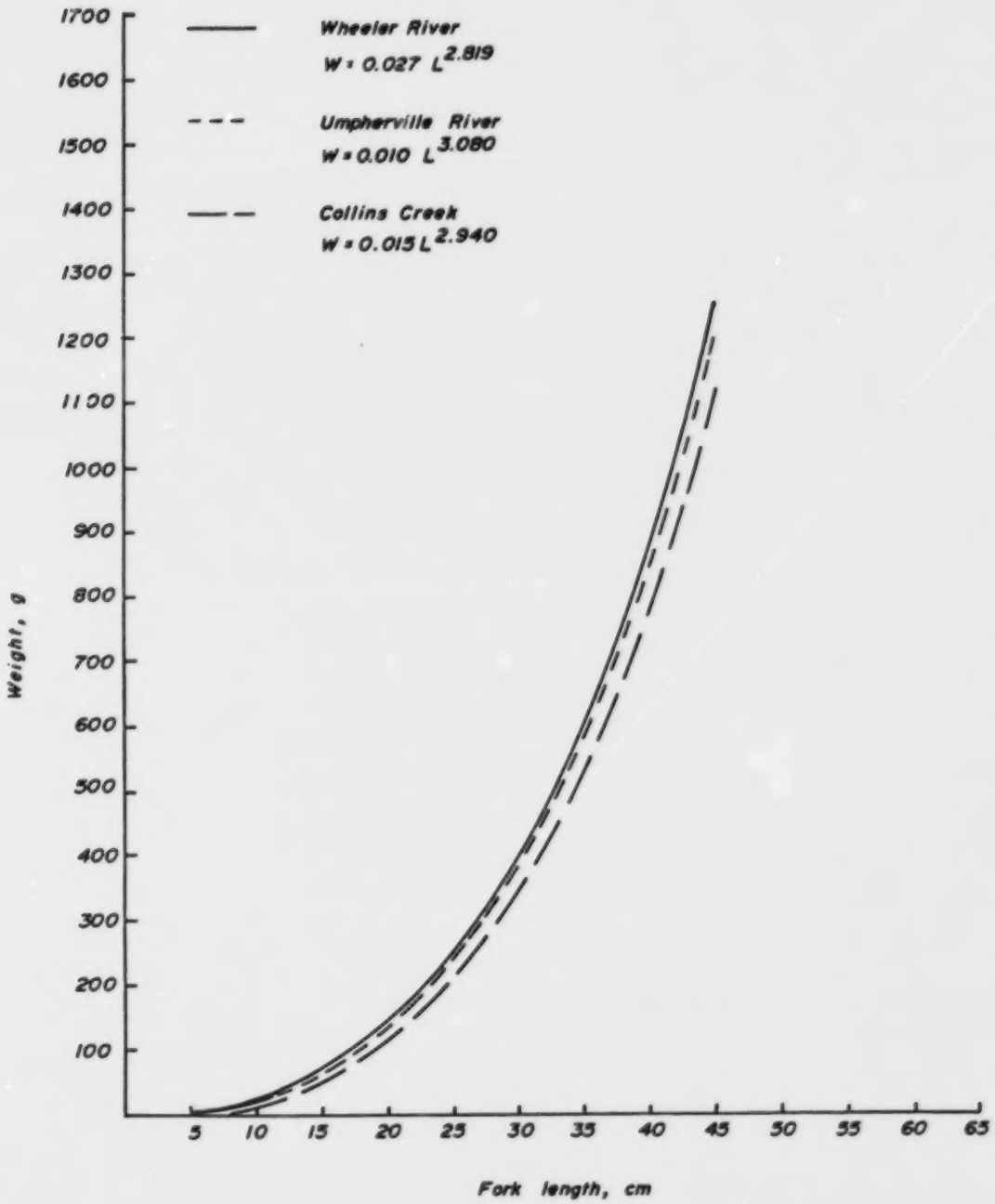

Fig. 11 Length weight relationships of grayling captured in the Wollaston Lake area, 1987-88.

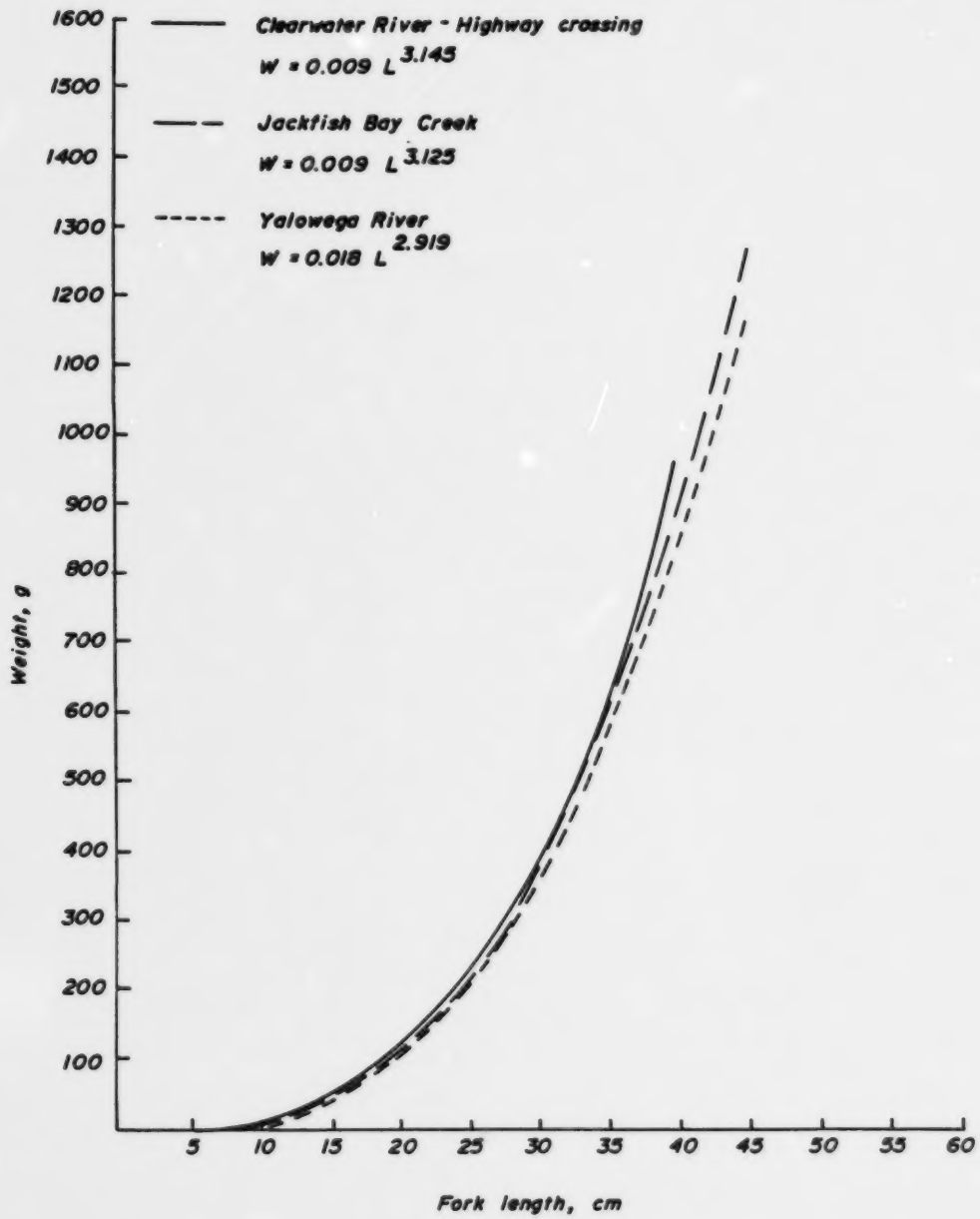

Fig. 12 Length weight relationships of grayling captured at Close Lake and the Clearwater River in 1988.

3.2.3 Age Composition and Growth

Grayling fry and juveniles were captured in sweep nets and by seining, lift-netting and setting fry nets. Growth of young-of-the-year grayling captured at various locations in northern Saskatchewan is indicated in Fig. 13. Growth is rapid during the summer, with young grayling attaining fork lengths of over 9 cm by mid-August. The slower growth rates of grayling at the Fond du Lac and Close Lake in early summer are probably due to later spring break-up and subsequent delay in spawning times at these particular locations.

Scales were collected from all grayling captured during the study for ageing purposes. Otoliths, pectoral fin rays and scales were collected from dead grayling so that results obtained from the different ageing structures could be evaluated. A comparison of scale ages with mean otolith ages (Table 4) and mean fin ray ages (Table 5) indicates that scales give reliable results for grayling up to 6 - 7 years of age. Since scales were taken from all fish sampled, and because most fish were less than 6 years of age, scales were used to estimate age composition and growth.

Age composition of grayling captured by hoop net, gillnet and by angling are depicted in Fig. 14 - 18. Ages of grayling captured ranged from 1 to 9 years. Age composition of grayling varied depending upon location. On the Fond du Lac (Fig. 17), most grayling were aged 3 - 5 years whereas in the Wheeler River (Fig. 16) most grayling were younger than 3 years. In Collins Creek and Umpherville River (Fig. 14)

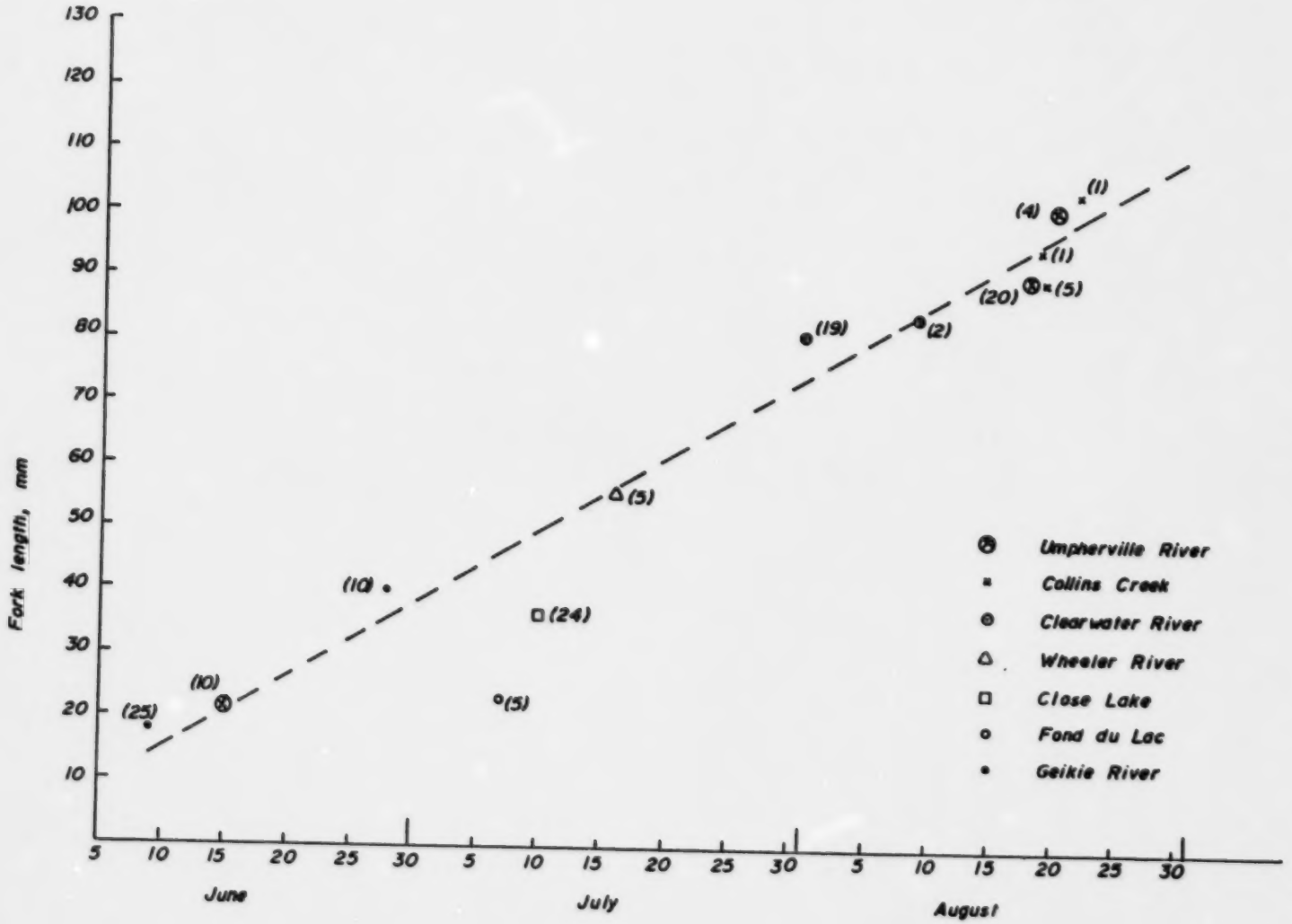

Fig. 13 Growth of young-of-the-year grayling captured at various locations in northern Saskatchewan, 1987 and 1988. Number in brackets is sample size. Line was fitted by eye.

Table 4. Comparison of scale ages and mean otolith ages of Arctic grayling in Saskatchewan, 1987 and 1988.

Scale age, yr	Mean otolith age, yr	Standard deviation	No. of fish
2	2.0	0.00	5
3	3.3	1.24	3
4	4.0	0.70	4
5	5.3	0.43	4
6	7.7	1.69	3
7	9.0	2.00	2
8	10.0	-	1

Table 5. Comparison of scale ages and mean fin ray ages of Arctic grayling in Saskatchewan, 1987 and 1988.

Scale age, yr	Mean fin ray age, yr	Standard deviation	No. of fish
1	1.0	-	1
2	2.0	0.00	13
3	3.0	0.00	6
4	4.2	0.57	11
5	5.3	0.45	10
6	6.3	0.43	4
7	7.7	0.94	3
8	10.0	-	1

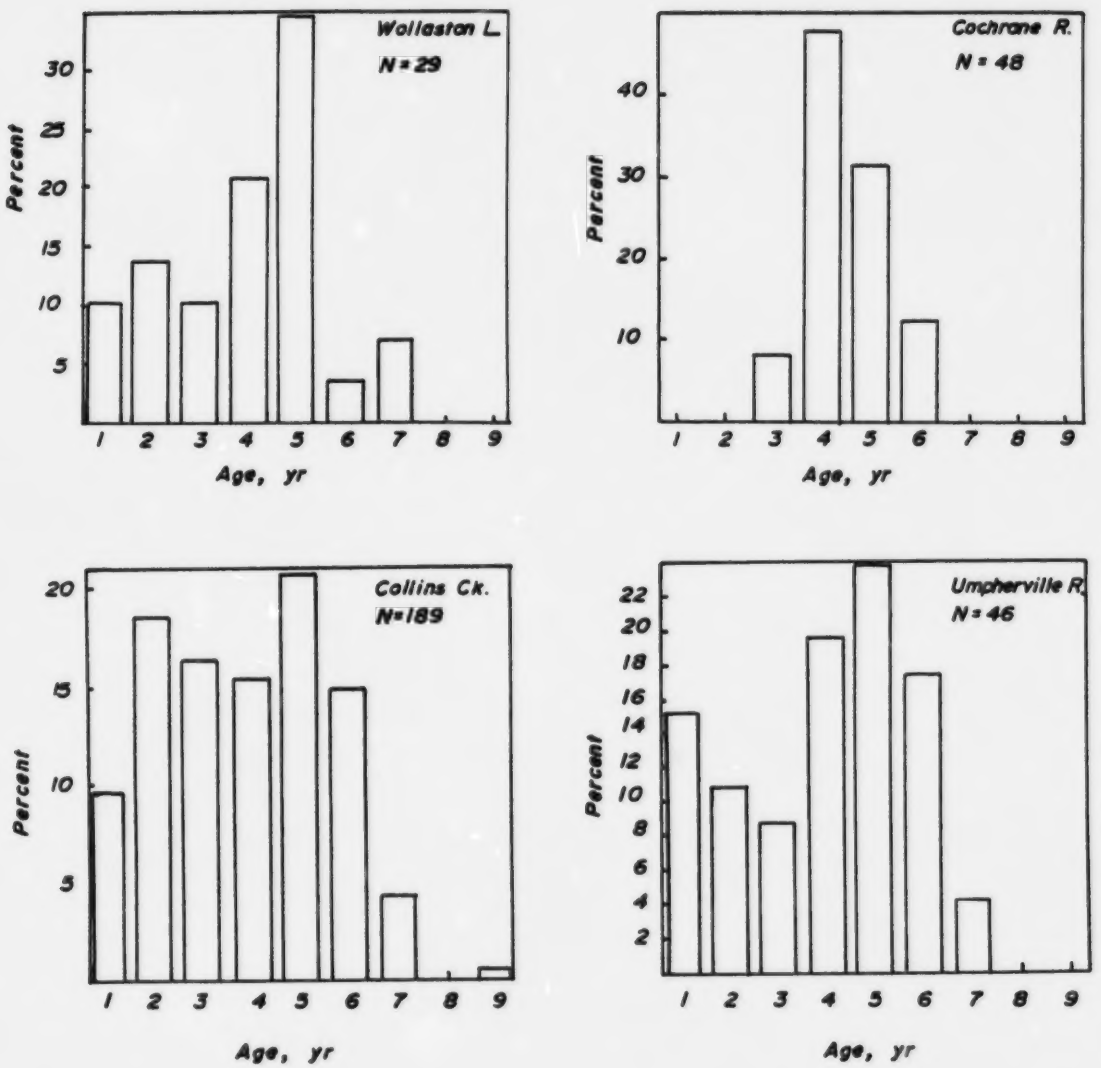

Fig. 14 Age composition of grayling captured at four locations in the Wollaston Lake area in 1987 and 1988. Ages were determined from scales. N = number of fish.

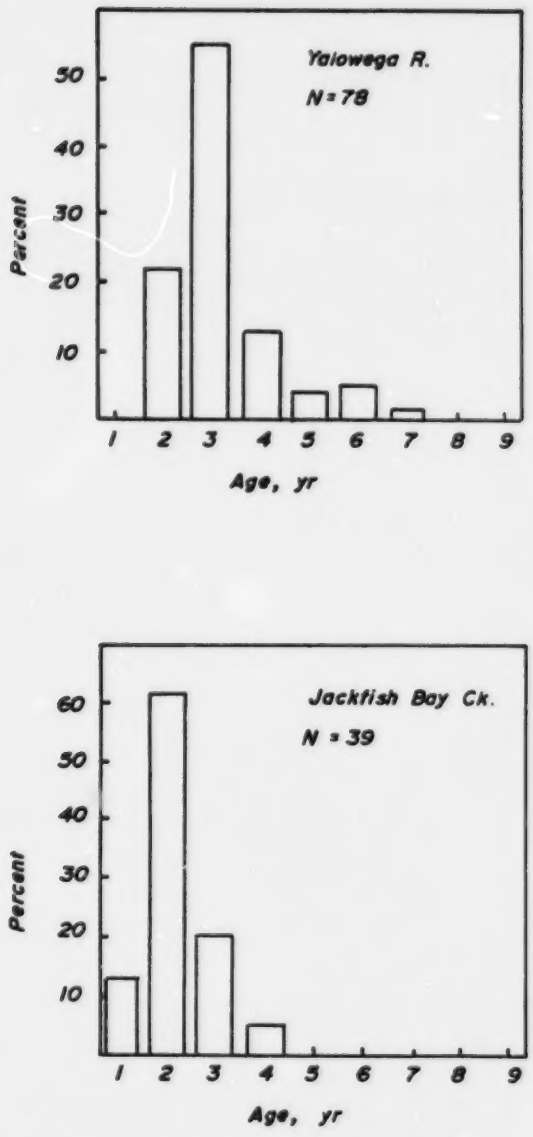

Fig 15 Age composition of grayling captured at two locations on Close Lake in 1988. Ages were determined from scales. N = number of fish.

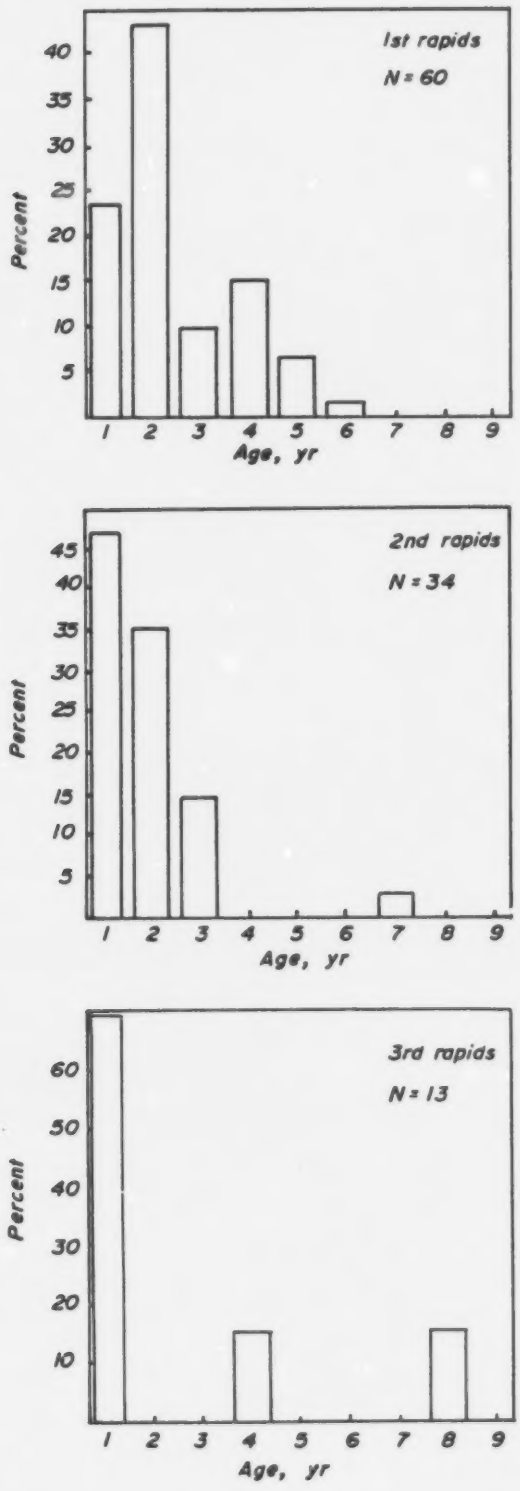

Fig. 16 Age composition of grayling captured at three locations on the Wheeler River in 1988. Ages were determined from scales. N= number of fish.

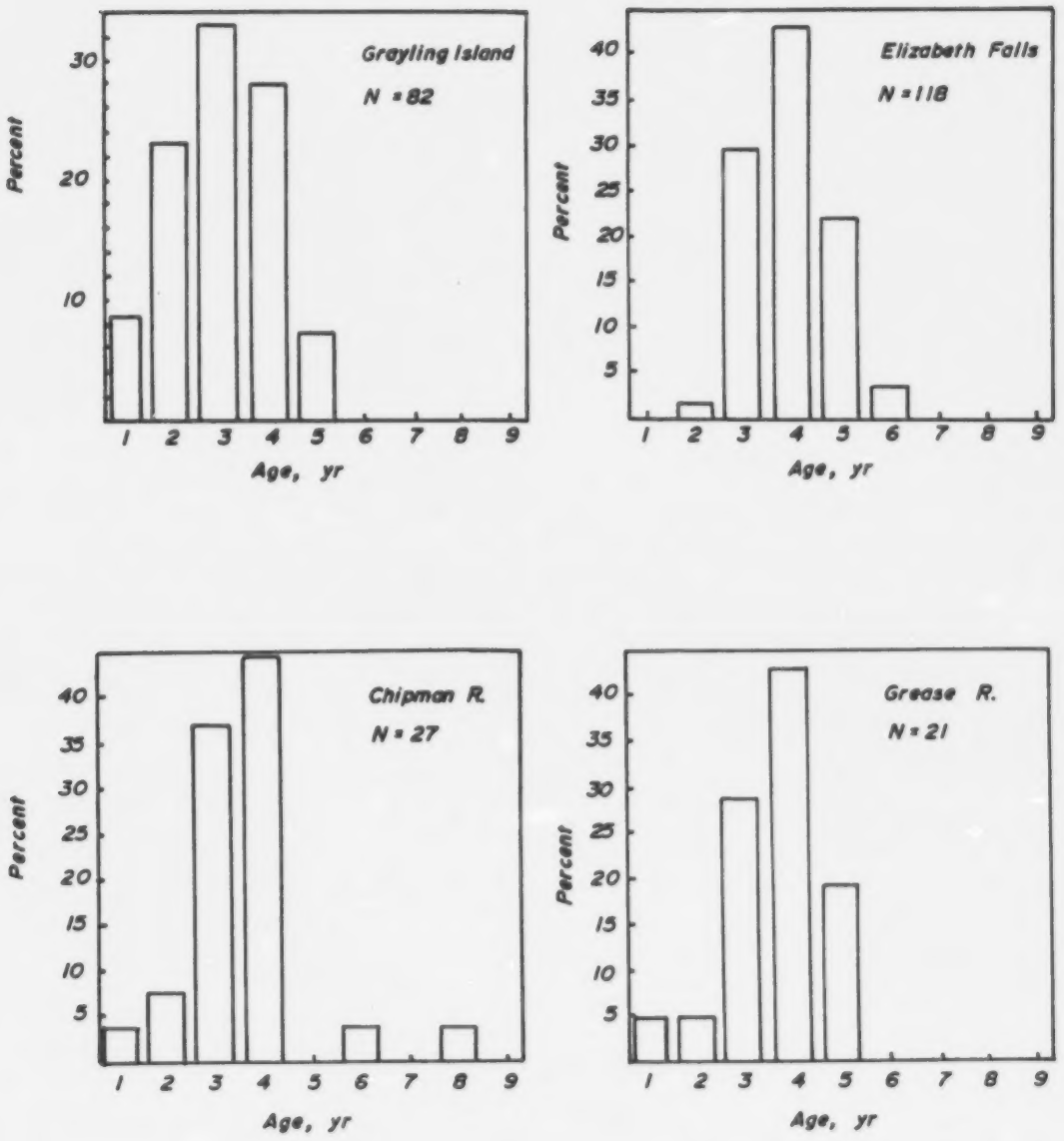

Fig. 17 Age composition of grayling captured at four locations in the Fond du Lac in 1987. Ages were determined from scales. N = number of fish.

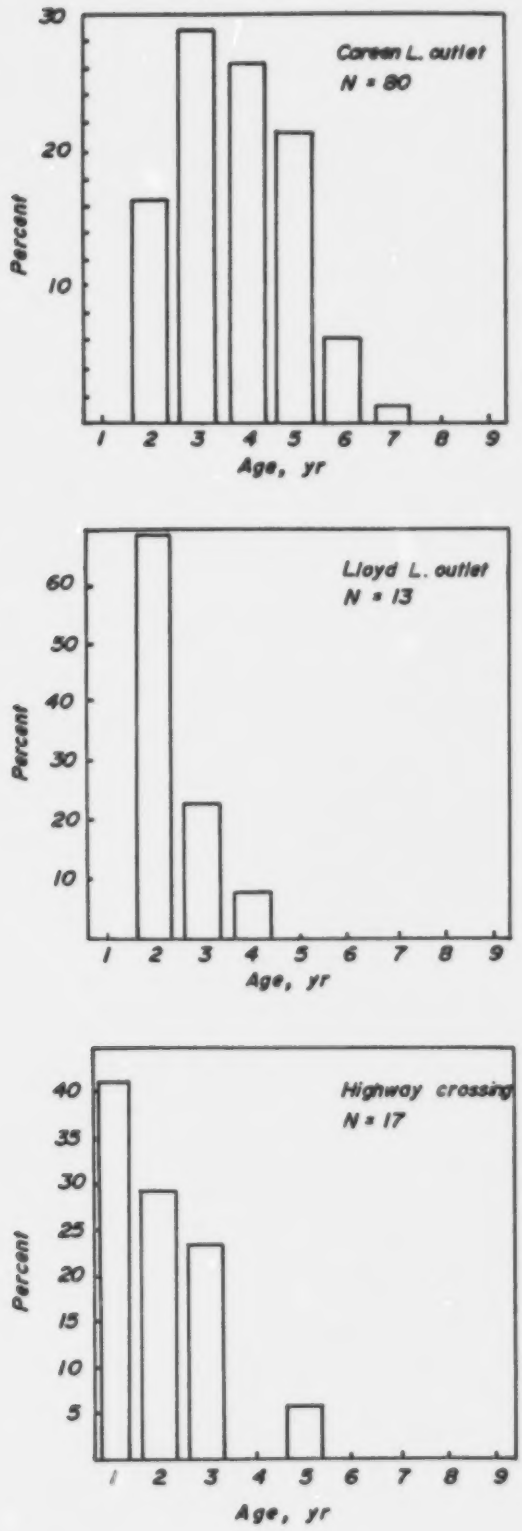

Fig. 18 Age composition of grayling captured at three locations on the Clearwater River in 1987 and 1988. Ages were determined from scales. N = number of fish.

proportions of grayling in each age class from 1 to 6 years were approximately equal.

Table 6 and Fig. 19 indicate growth of grayling in various waterbodies in northern Saskatchewan. Data on the ages of grayling from several sites on each stream were combined (eg. both sets of rapids in the Umpherville River) to increase the sample size. Determination of ages for grayling at Grayling Island on the Fond du Lac were kept separate from Elizabeth Falls and Middle Lake inlet, because the falls provide a barrier that prevents mixing of the populations (Kratt 1977). Some variation in grayling size by age occurs in different streams, although the range in mean length by age was usually less than 50 mm. Grayling captured in the Fond du Lac and Clearwater River systems appeared to grow faster than those in other waterbodies.

3.2.4 Reproduction

Grayling reproduction in Saskatchewan occurs from mid-May to mid-June, depending upon the arrival of spring and subsequent ice break-up. In 1987, field work commenced on May 21. Several male and female grayling in spawning condition were captured by angling at Bigstone Rapids on the Cochrane River on June 4. This river is the major outflow of Wollaston Lake. No grayling captured at other locations appeared to be ripe and it was assumed spawning had already occurred. In 1988, a cold, late spring and earlier starting date for field work permitted grayling reproduction to be observed in the Wollaston Lake area.

Table 6. Growth of grayling (fork length cm) in water bodies in northern Saskatchewan. Ages are based on scales. Water bodies listed in order of decreasing fork lengths at age 3^{+}.

	Age, yr								
	1	2	3	4	5	6	7	8	9
Pond du Lac - at Black L. outlet	20.7	26.4	34.7	37.6	41.4	42.7*	-	-	-
Clearwater River	27.3	28.4	33.2	38.2	40.4	42.4	43.6*	-	-
Cochrane River	-	-	31.8	35.8	37.7	39.3	-	-	-
Umpherville River	19.9	25.2	30.2	36.4	39.0	39.7	39.2	-	-
Chipman River	19.9*	20.8*	29.7	34.5	-	35.8*	-	37.6*	-
Wheeler River	17.1	23.8	29.6	31.1	33.6*	39.3*	39.1*	40.3*	-
Grease River	18.9*	20.5*	29.1	31.7	32.5*	-	-	-	-
Wollaston Lake	18.8	21.3	28.3	31.3	35.6	36.9	39.1	-	-
Collins Creek	18.1	23.2	28.2	31.5	34.6	36.2	37.1	-	38.9
Close Lake	14.6	21.5	27.5	33.0	36.3*	37.6*	39.2*	-	-

*Sample based on less than 5 specimens

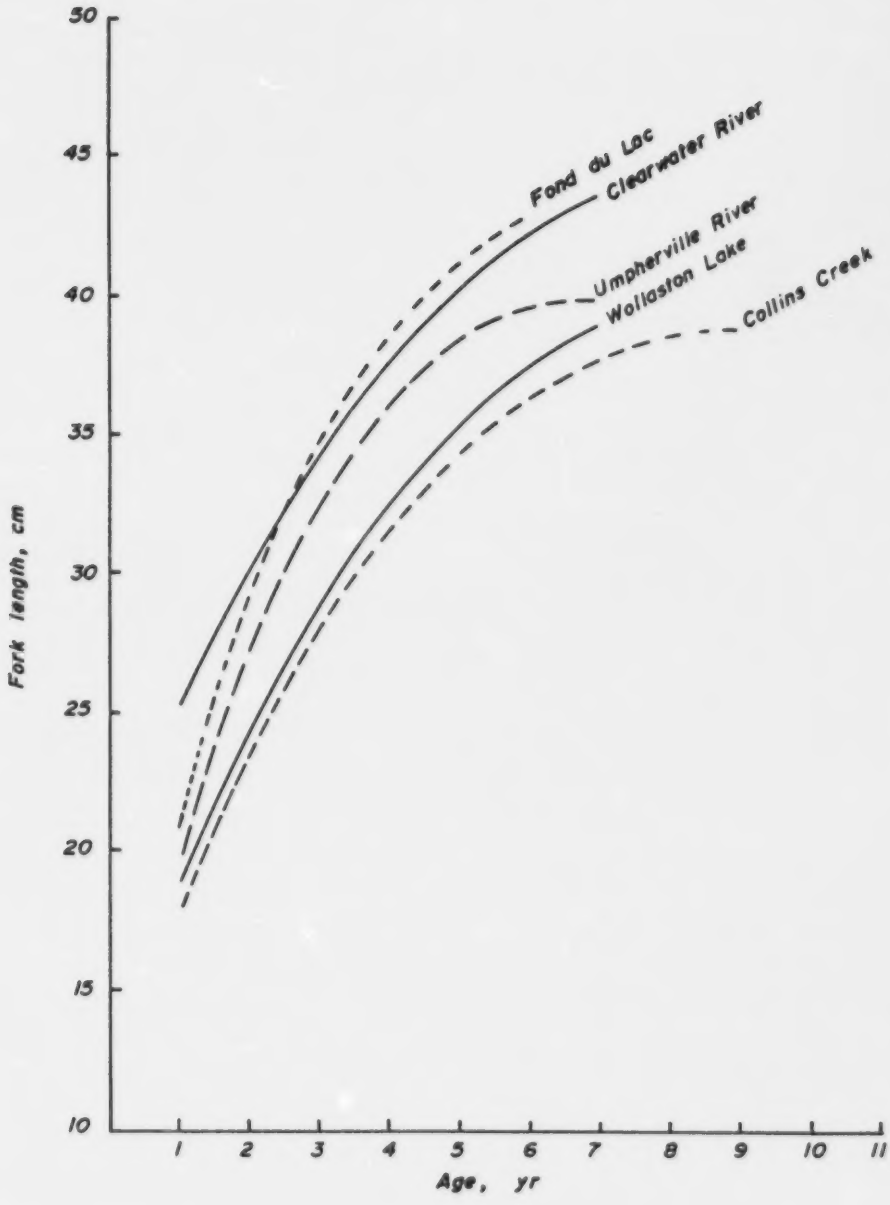

Fig. 19 Growth of grayling (mean size at age) at several locations in northern Saskatchewan during 1987 and 1988. Ages were determined from scales.

Grayling in spawning condition were captured in hoopnets and by angling in Collins Creek and Umpherville River between May 21-26, 1988. Both of these streams are tributaries to Wollaston Lake. Water temperatures measured in Collins Creek on these dates fluctuated between 3.0° and 11.0°C.

Date	Minimum temperature, °C	Maximum temperature, °C
May 21	3.5	7.0
May 22	3.5	7.0
May 23	3.0	7.5
May 24	6.0	8.0
May 25	6.5	10.0
May 26	7.5	11.0

Although Wollaston Lake was still ice-covered during this time, headwater lakes to Collins Creek and Umpherville River were breaking up.

Grayling in reproductive condition captured in the Wollaston Lake area ranged between 3 - 9 years in age. Over 80% of the spawning males and females were 4 - 6 years (Table 7). No grayling younger than 2 years were mature. All fish 4 years of age and older were in spawning condition. These fish ranged in size from 30-42 cm in fork length with the exception of one male that measured 26.0 cm. Average size of spawning fish was 35.9 cm for females and 34.0 cm for males.

Table 7. Reproductive condition of grayling captured in northern Saskatchewan during 1987 and 1988.

	Females				Males			
Age	No. of immature	No. of mature	Total	% mature	No. of immature	No. of mature	Total	% mature
1	1	0	1	0.0	0	0	0	0.0
2	3	0	3	0.0	5	0	5	0.0
3	0	3	3	100.0	1	1	2	50.0
4	0	12	12	100.0	0	8	8	100.0
5	0	8	8	100.0	0	7	7	100.0
6	0	9	9	100.0	0	7	7	100.0
7	0	2	2	100.0	0	2	2	100.0
8	0	2	2	100.0	0	1	1	100.0
9	0	1	1	100.0	0	0	0	0
Total	4	37	41	0	6	26	32	

Examination of grayling gonads in spring in the Wollaston Lake area indicated that some females that were of spawning size (> 37 cm) contained immature eggs. This suggests that female grayling may not spawn every year. Conclusions about the spawning frequency of male grayling could not be made.

Habitat where grayling in spawning condition were captured consisted of waters with substrates comprising gravel (0.5 - 7.4 cm diameter), rubble (7.5 - 30.4 cm diameter) and boulders (>30.5 cm diameter), with rubble predominant. Grayling eggs were collected in this bottom material during the last week of May and first week of June 1989 at the Umpherville River and Geikie River. The eggs were collected in rapids adjacent to shore in waters less than 1 m deep, using a sweep net and Surber sampler. Eggs developed to the eyed stage by early to mid-June, at which time they measured 3-4 mm in diameter.

Grayling also spawn along the shores of lakes and islands. Juvenile grayling were captured using a seine net along several sandy beaches in Close Lake in July, 1988. Although passive downstream drifting of grayling fry may occur for about 2 weeks after hatching (Nelson 1954), the beaches where fingerlings were collected were not near any tributaries, so it is unlikely that the grayling fry had hatched in a stream. Juvenile grayling were observed in a pool surrounded by large boulders off a small island north of North Island in Wollaston Lake on August 17, 1988. Although grayling fingerlings may move downstream from inlet nursery areas in the fall (Craig and Poulin

1975), the lack of tributaries in the vicinity makes it unlikely that the grayling had spawned in a stream and that the juveniles had moved into the lake.

Grayling fry were collected by Surber sampler and sweep net in backwater areas of streams in June, 1988 in the Geikie and Umpherville Rivers. Schools of juveniles were observed in the same areas in July, as well as in backwater areas in the Wheeler River. By August, the juveniles had moved out into the current where they could be captured using a small mesh fry net.

3.2.5 Mortality

Annual mortality rates for grayling at various locations in northern Saskatchewan were determined from age frequencies, based on the method described by Rounsefell and Everhart (1953):

Location	Ages included	Mortality rate %
Collins Creek	3-7	29.4
Fond du Lac		
Grayling Island	4-5	35.4
Wheeler River	2-6	43.5
Clearwater River	4-7	49.2
Close Lake	4-7	54.6
Fond du Lac		
Elizabeth Falls	5-6	66.8

Mortality of grayling ranged from 29.4% at Collins Creek to 66.8% at Elizabeth Falls on the Fond du Lac. Although it was not possible to separate the natural mortality and fishing mortality components, the rate of angling removal (as indicated from tag returns) is probably less than 13% (see section 3.3.1). Many anglers regard grayling as a catch and release species (section 3.4.2) and in general, less than 50% of the grayling captured are retained. There is some mortality involved with catching and releasing grayling. Using barbless hooks, estimated angling mortality (short-term) of grayling captured during the study was 1.9%. This rate is comparable to the 5.1% mortality grayling suffered when barbless hooks were used in the Great Slave Lake area (Falk and Gillman 1975).

3.2.6 Food Habits

Occurrence of food organisms in young-of-the-year grayling is given in Table 8. In June and July, Dipterans (flies) comprised over 70% of the stomach composition by volume, and chironomids were the dominant group. In August, Trichoptera (caddisfly) larvae and pupae made up over 50% of the food items encountered followed by Diptera (flies; 28.2%) and Ephemeroptera (mayfly; 17.9%). Zooplankton made up less than 5% of the stomach contents during the summer. Miscellaneous items eaten by young grayling included leeches, nematodes, plant material and insect eggs.

Table 8. Stomach contents of young-of-the-year grayling, 1987 and 1988.

Organism	% Composition by volume			
	June	July	August	Average
Insecta:				
Ephemeroptera - unidentified	1.92	1.81	5.00	2.27
Baetidae	0.77	4.74	10.00	4.39
Caenidae	0.00	0.34	0.00	0.20
Ephemerellidae	0.00	3.28	2.86	2.32
Heptageniidae	1.92	0.34	0.00	0.71
Hemiptera - unidentified	0.00	1.72	0.00	1.01
Odonata	1.15	0.00	0.00	0.30
Trichoptera - unidentified	15.38	3.71	21.43	9.24
Hydropsychidae	0.00	5.52	27.86	7.17
Leptoceridae	0.00	0.00	3.21	0.45
Philopotamidae	0.00	0.00	1.43	0.20
Diptera - unidentified	3.08	13.97	0.00	8.99
Ceratopogonidae	0.00	0.09	0.00	0.05
Chironomidae	59.81	41.72	26.07	43.84
Simuliidae	7.69	18.71	2.14	13.28
Cladocera	3.65	3.45	0.00	3.03
Copepoda	0.77	1.03	0.00	0.81
Nauplius	0.00	0.34	0.00	0.20
Hirudinea	0.19	0.00	0.00	0.05
Nematoda	0.00	0.17	0.00	0.10
Insect eggs	0.00	0.09	0.00	0.05
Plant material	0.00	0.34	0.00	0.20
Unidentified	3.08	0.34	0.00	1.01
No. empty	0.00	1.00	0.00	0.00
No. examined	26.00	59.00	14.00	0.00

Analyses of 61 adult grayling stomachs indicate that this species relies mostly on aquatic insects for its diet (Table 9). Overall, caddisflies, particularly the family Hydropsychidae, were the major organisms ingested, followed by Diptera, Coleoptera (beetles), mayflies and Hemiptera (aquatic bugs). Miscellaneous items eaten by adult grayling included plant material, Nematomorpha (horsehair worms), fish, leeches and fish eggs. The fish eggs were from trout-perch.

The difference in diet between grayling captured in May, June and July as compared to August is because the majority of specimens caught in August were from Wollaston Lake. In early and mid-summer, most grayling were captured in streams. Lake grayling appear to feed almost exclusively on terrestrial organisms, including beetles, wasps, grasshoppers and spiders.

Of the 61 adult grayling examined, only 2 fish had empty stomachs.

3.3 POPULATION DYNAMICS

3.3.1 Marking and Tag Recovery

Table 10 indicates numbers of grayling tagged and recaptured at each of the locations studied in northern Saskatchewan. A total of 1 140 grayling were tagged over the two years. To date, 147 tagged grayling have been recaptured, a recovery rate of 12.9%. Recaptures include fish captured by anglers and also by the Fisheries Branch staff working on the project. Numbers of grayling recaptured at the different

Table 9. Stomach contents of adult grayling, 1987 and 1988.

	% Composition by volume				
	May	June	July	August	Average
Aquatic organisms					
Coleoptera	0.00	1.67	1.36	10.75	4.41
Dytiscidae	1.25	7.22	1.36	0.00	1.78
Elmidae	0.00	2.22	0.23	0.00	0.42
Staphylinidae	0.38	0.00	0.00	0.00	0.05
Ephemeroptera - unidentified	0.63	0.00	1.82	0.00	0.76
Ephemerellidae	0.38	0.00	2.50	0.00	0.98
Baetidae	1.00	1.67	5.45	0.50	2.59
Heptageniidae	7.75	0.00	0.00	0.00	1.05
Hemiptera	0.00	0.00	0.00	0.00	0.00
Corixidae	7.50	10.00	1.82	2.00	3.90
Gerridae	1.88	0.00	0.91	0.00	0.59
Hebridae	0.00	0.00	0.00	2.50	0.85
Odonata - unidentified	3.13	1.11	2.95	3.50	2.88
Gomphidae	11.88	0.00	0.00	0.00	1.61
Plecoptera - unidentified	1.88	6.67	0.68	1.50	2.03
Nemouridae	3.13	0.00	0.00	0.00	0.42
Perlodidae	0.00	5.56	1.14	0.00	1.27
Trichoptera - unidentified	2.50	0.00	14.55	4.00	7.12
Brachycentridae	2.50	0.00	1.82	0.50	1.19
Hydropsychidae	12.25	30.56	24.09	5.50	17.17
Leptoceridae	17.63	4.44	2.95	3.50	5.36
Limnephilidae	0.00	0.00	0.45	0.00	0.17
Rhyacophilidae	0.25	0.00	0.00	0.00	0.03
Diptera - unidentified	0.00	0.00	0.00	3.00	1.02
Ceratopogonidae	0.63	0.56	9.77	0.00	3.81
Chironomidae	2.75	7.22	5.68	1.75	4.19
Simuliidae	3.75	4.44	6.14	1.00	3.81
Nematomorpha	0.00	0.00	0.00	0.50	0.17
Hirudinea	0.00	0.00	2.27	1.00	1.19
Oligochaeta	0.00	0.00	0.00	0.50	0.17
Plant material	11.25	5.56	9.09	8.00	8.47
Fish eggs	0.00	0.00	1.36	0.00	0.51
Fish remains	0.00	0.00	0.68	0.00	0.25
Unidentified	3.13	7.78	0.45	25.75	10.51
Total	97.43	96.68	99.52	75.75	90.73
Terrestrial organisms:					
Coleoptera	0.63	3.33	0.91	0.75	1.19
Hymenoptera	0.00	0.00	0.00	18.25	6.19
Orthoptera	0.00	0.00	0.00	3.50	1.19
Spiders	0.63	0.00	0.00	0.75	0.34
Unidentified	1.25	0.00	0.00	0.00	0.17
Total	2.51	3.33	0.91	23.25	7.89
No. empty	0	0	2	0	
No. examined	8	9	24	20	61

Table 10. Numbers of grayling tagged and recaptured at various locations in northern Saskatchewan, 1987 and 1988.

Location	No. tagged	No. tags returned	% returned
1. Wollaston Lake Area:			
Wollaston Lake	11	0	0
Collins Creek	217	40	18.4
Umpherville River	67	18	26.9
Cochrane River	59	3	5.1
Waterfound River	6	1	16.7
Geikie River	10	2	20.0
Yalowega River (Close Lake)	86	43	50.0
Jackfish Bay Creek (Close Lake)	40	7	17.5
Wheeler River	110	2	1.8
2. Fond du Lac Area:			
Grayling Island	117	11	9.4
Elizabeth Falls (and Middle Lake)	219	17	7.8
Chipman River	41	0	0
Grease River	25	0	0
Woodcock Rapids	10	0	0
3. Clearwater River Area:			
Careen Lake Outlet	91	3	3.3
Lloyd Lake Outlet	13	0	0
Highway 955 Crossing	18	0	0
Total	1140	147	12.9

areas varied from 0 on Wollaston Lake, Chipman River, Grease River, Woodrock Rapids, and two locations on the Clearwater River to 50% at Yalowega River. As indicated in Appendix 9, many fish were caught and released several times, sometimes in the same day.

Twenty-five grayling tagged in one year were recaptured the following year (Appendix 9). With the exception of several fish tagged in the Umpherville River, all recaptures occurred at the tagging location. Maximum number of 'days at large' was 425 for a grayling tagged at Bigstone Rapids on the Cochrane River on June 4, 1987. It was recaptured on August 3, 1988.

The low rate of tag returns at some of the areas may be due in part to lack of fishing pressure. For example, access to Lefty Falls on the Grease River is by aircraft only. Currently, no camps exist at this location, although one of the lodges situated on the Fond du Lac at Black Lake outlet may use the area for a day camp in the future. The Chipman River is boat accessible but the falls where the grayling were sampled require a several mile hike through the bush to be reached. In addition, the low numbers of grayling tagged in some of the locations make it unlikely that recaptures would occur.

3.3.2 Tag Loss and Tag Mortality

Several areas in the Wollaston Lake area were sampled intensively for grayling in both 1987 and 1988. In particular, much time was spent on Collins Creek and Umpherville River, and since many

grayling were captured and released at these locations, estimates of tag loss could be made. The estimating procedure was based on a comparison of numbers with tags missing against total recaptures initially tagged. Double tagging was not carried out. Loss of the Monel metal strap tag leaves a visible scar on the fish, and this scar was retained even a year after tagging. Of the 64 grayling recaptured at the Umpherville River and Collins Creek, only 8 had tag scars. This gives a rate of tag loss of 12.5% at these areas, comparable to the rate of 14.4% determined for the same tag on lake trout in Lac la Ronge (Chen 1979). Thus, the majority of grayling appear to retain Monel tags for at least one year. Longer retention times could not be determined.

Effects of tagging on fish were investigated in spring, 1988. Ten grayling, five of them tagged and five untagged, were put into a holding pen in Collins Creek for one week. The grayling were fed daily by collecting invertebrates with a sweep net. After seven days, the grayling were examined and released. All of the grayling, both tagged and untagged, were healthy and robust. Tagging appears to have had no immediate adverse effects on grayling. Tagged grayling that were recaptured a year after marking also appeared healthy with the tag intact. Scar tissue had formed around the tag, and although the puncture wound was larger than when the tag was first inserted, there was no apparent infection. In an earlier study, the monel metal tag caused no higher mortality on marked bream than when compared to control and fin-clipped fish (Goldspink and Banks 1971).

3.3.3 Estimation of Population Sizes

Data collected from marking and recapturing grayling were used to estimate grayling population sizes at various locations in northern Saskatchewan. Two types of procedures were used in making the estimates. For grayling populations at the Waterfound River and Bigstone Rapids on the Cochrane River, a single census (Petersen type) procedure was used (Ricker 1975). At these two locations, marking was done on a single day. From the angling results of the 1987-88 creel census, grayling population estimates (N) were calculated for the two areas (Appendix 10):

Waterfound River N = 18 591

Cochrane River N = 24 588

There is probability of statistical bias in the estimate for the Waterfound River because of the low number of recaptures (R=1). According to Ricker (1975), the probability of statistical bias exists if recaptures number < 3 - 4. Estimates for both these waterbodies may be high because unmarked fish caught were not necessarily removed from the population. Grayling in these two areas are generally captured and released (see section 3.4.2), thus the same fish may have been caught several times. This would cause the sample, C, from the anglers' catch to be high and the population size would be overestimated.

For grayling populations in other locations, fish were marked over a period during which time samples were taken and examined for recaptures. A multiple census (Schnabel type) procedure was used to estimate population sizes (Ricker 1975). For these estimates, each day of marking was considered to be a time interval, t. Mt was the total marked fish at large at the start of the t^{th} day (i.e. the number previously marked less any accidentally killed at previous recaptures); Mt was the total number marked; Ct was the total sample taken on day t; Rt the number of recaptures in the sample Ct; and ΣRt was the total recaptures during the experiment (Ricker 1975). The sample Ct for these estimates was the catch of the Fisheries Branch staff on day t, while recaptures, Rt, were only those tagged fish caught by the Fisheries Branch. By using these parameters, errors due to incomplete records of unmarked grayling catches, incomplete records of tagged grayling recaptures, and catch and release of the same fish several times could be avoided. Appendix 11 illustrates the Schnabel method for deriving population estimates for the Umpherville River.

Table 11 summarizes grayling population estimates for various areas in northern Saskatchewan. Population sizes ranged from an estimated 91 grayling at Jackfish Bay Creek, a small tributary to Close Lake, to almost 25 000 at Bigstone Rapids on the Cochrane River. Rates of exploitation were determined for grayling populations in several areas of the province using the ratio of number of tags returned by anglers (Appendix 9) to number of fish marked (Table 10). Results are

Table 11. Summary of grayling population estimates for various areas in northern Saskatchewan in 1987 - 1988.

Population	Method	Estimated no. of individuals per area	95% confidence range
Wollaston Lake Area:			
Cochrane River	Petersen	24 588	11 176 - 163 922
Waterfound River*	Petersen	18 591	6 640 - 371 820
Wheeler River*	Schnabel	2 380	661 - 23 800
Collins Creek	Schnabel	726	518 - 1 056
Umpherville River	Schnabel	225	126 - 459
Yalowega River	Schnabel	115	83 - 165
Jackfish Bay Creek	Schnabel	91	42 - 247
Fond du Lac Area:			
Grayling Island*	Schnabel	5 024	897 - 50 240
Elizabeth Falls	Schnabel	3 844	1 643 - 12 012
Clearwater River Area:			
Careen Lake Outlet*	Schnabel	1 662	462 - 16 620

*Sampling bias may be a factor as number of recaptures at these areas was < 3 - 4 (Ricker 1975).

given in Table 12. Rates of exploitation varied from 1.1% at Careen Lake to 9.0% at the Umpherville River.

There are several sources of error that may affect computations of population estimates. As previously mentioned, incomplete records of grayling catches, unreported or unrecognized catches of tagged fish and capture of the same fish several times would all cause errors in the estimates. Other errors may be due to loss of tags, mortality (both fishing and natural) and recruitment (Ricker 1975) that were not incorporated into the computations. Therefore, data generated on population statistics must be used with caution and not taken as absolute values.

3.4 EXPLOITATION

3.4.1 The Commercial and Domestic Fisheries

Although grayling are known to occur in some of Saskatchewan's northern lakes (Athabasca, Close, Cree, Reindeer and Wollaston Lakes), they are not a species exploited by the commercial fishery. Grayling tend to live in rocky areas adjacent to shore and these areas are not readily accessible to gillnet fishing.

In the past, grayling were harvested by the domestic fishery. Nets were set at the outlet of Black Lake during spring when the grayling congregated on their spawning beds. Grayling captured were

Table 12. Exploitation rates of grayling from various locations in northern Saskatchewan during 1987 - 1988.

Location	No. of fish marked, M	No. of fish recaptured by anglers, R	Rate of exploitation, R/M x 100
Wollaston Lake Area:			
Collins Creek	217	5	2.3
Jackfish Bay Creek	40	1	2.5
Cochrane River	59	3	5.1
Yalowega River	86	7	8.1
Umpherville River	67	6	9.0
Fond du Lac Area:			
Grayling Island	117	10	8.6
Elizabeth Falls	219	10	4.6
Clearwater River Area:			
Careen Lake Outlet	91	1	1.1

used primarily as food for dogs and to a lesser extent as a food source for the fishermen and their families. In the spring local residents still set gillnets at the outlet of the river and catch spawning grayling (Calvin Parobec, manager of Morberg's Camp, pers. comm.) During the summer months, domestic fishermen were observed catching large numbers of grayling at Elizabeth Falls using fishing line and tackle. The majority of the fish captured were retained. Domestic fishing also occurs in the riffle area of the Fond du Lac at Stony Rapids (Rick Goett, conservation officer, pers. comm.). The amount of fish utilized by the local population is unknown. However, with decreasing dog populations and changing food habits among residents, domestic production has probably declined in recent years.

3.4.2 The Sport Fishery - Angler Information

Utilization of grayling populations in Saskatchewan is primarily by the sport fishery.

Data on 984 anglers fishing for grayling in northern Saskatchewan are given in Table 13. Information was collected from interviewing anglers on site, from the self-registering creel stations, and from records kept by lodges in the study area. Conservation officers in the areas also helped collect angler statistics.

An estimated 3 782 angler-hr were expended by grayling fishermen at the study sites in 1987-88, during which they captured almost 10 000 grayling. These estimates are conservative because

Table 13. Angler information collected at various locations in northern Saskatchewan during 1987 - 1988. Data was collected only after grayling had been tagged in the area.

Location	No. of anglers	Angler-hr	No. of grayling caught	No. of grayling kept	% kept	Fish/ angler	Fish/ hr
Wollaston Lake Area:							
Collins Creek	48	133	109	33	30.3	2.3	0.8
Umpherville River	137	257	217	42	19.4	1.6	0.8
Cochrane River	187	586	1666	183	11.0	8.9	3.8
Wheeler River*	53	472	43	2	4.7	0.8	0.1
Geikie River	98	653	103	83	80.6	1.1	0.2
Waterfound River	241	1018	6196	295	4.8	25.7	6.1
Fond du Lac Area:							
Grayling Island	34	70	381	14	3.7	11.2	5.5
Elizabeth Falls	74	186	292	105	36.0	4.0	1.6
Clearwater River Area:							
Careen Lake	112	407	217	82	37.8	1.9	0.5
Total	984	3782	9224	839	9.1	9.4	2.4

*Angler-hr at the Wheeler River included time spent fishing for other species. Grayling catches were usually incidental. Numbers of fish captured per angler and per angler-hr are not representative of the grayling fishing success at this site.

anglers records at many of the locations are incomplete. A wide variation in angler success rates occurred, with numbers of grayling caught ranging from a minimum of 1.1/angler and 0.2/angler-hr on the Geikie River to a maximum of 25.7/angler and 6.1/angler-hr at the Waterfound River (data on Wheeler River were not considered representative of its grayling fishery). In general, success was highest at the more remote fly-in locations (Waterfound River, Fond du Lac) than road accessible sites (Umpherville River, Geikie River).

Numbers of grayling kept by anglers varied from 3.7% of their total catch at Grayling Island on the Fond du Lac to 80.6% on the Geikie River. Anglers tended to keep fewer than half the grayling they caught. Many northern outfitters request that their clients fish for grayling as catch and release only, accounting for the low harvest rates.

When asked what species of fish they preferred to catch, over 50% of the anglers chose grayling (Table 14). Lake trout ranked second (19.8%) followed by walleye (14.2%) and pike (11.3%). Only 1.9% of those interviewed had no preference.

As indicated in Table 15, over 80% of the anglers contacted stayed in northern fishing lodges. Fewer than 10% of the anglers stayed in a private cabin or residence. Only 7.9% of the anglers stayed in one of the provincial campgrounds or camped in a non-designated area.

Information on age and sex of anglers and where they live was obtained from on-site interviews and also from the creel survey

Table 14. Species of fish that anglers in northern Saskatchewan preferred to catch during 1987 - 1988.

Species	No. of Anglers	%
Grayling	56	52.8
Lake Trout	21	19.8
Walleye	15	14.2
Pike	12	11.3
No preference	2	1.9
Total	106	100.0

Table 15. Number of anglers and where they stayed while fishing for grayling in northern Saskatchewan during 1987 - 1988.

	No. of anglers	%
Private cabin or residence*	54	7.8
Campground	55	7.9
Lodge	586	84.3
Total	695	100.0

*Includes people working and staying at Eldor Mine and residents of Stony Rapids.

stations. This information was not available for the majority of anglers who stayed at the lodges. As indicated in Table 16, the majority of anglers (83.8%) were aged 21-64 years. Young people under 16 years comprised 8.5% of the angling population. Anglers aged 16-20 years and senior citizens represented 5.4% and 2.3%, respectively, of anglers contacted. Male anglers outnumbered females by almost 10:1.

Over 60% of the anglers contacted were Saskatchewan residents (Table 17). Proximity to northern Saskatchewan did not appear to be a factor, as only 4.4% of the anglers resided in Prince Albert whereas over 13% came from Regina. Other Canadians comprised less than 5% of the anglers while Americans represented 35.2% of the angling population. Citizens from as far away as Florida, Texas and Maryland came to northern Saskatchewan to fish. The proportion of Americans in the angling population would have been much higher had lodge clientele been included because many of the northern lodges cater mainly to residents of the United States.

4. DISCUSSION

4.1 ASSESSMENT OF THE POPULATIONS

The waterbodies examined for grayling during 1987 and 1988 in Saskatchewan are typical of oligotrophic northern waterbodies. Dissolved ionic constituents were low and pH was near neutral, which are characteristic of waters situated on the Precambrian Shield (Liaw and Atton 1981).

Table 16. Age and sex of anglers fishing for grayling in northern Saskatchewan during 1987 - 1988.

Age, yr	Males		Females		Total	
	No.	%	No.	%	No.	%
<16	11	8.5	0	0	11	8.5
16 - 20	7	5.4	0	0	7	5.4
21 - 64	101	77.7	8	6.1	109	83.8
65+	2	1.5	1	0.8	3	2.3
Total	121	93.1	9	6.9	130	100.0

Table 17. Origin of anglers fishing for grayling in northern Saskatchewan during 1987 - 1988+.

	No. of anglers	%
Local*	15	9.4
Prince Albert	7	4.4
Saskatoon	17	10.7
Regina	22	13.8
Other Saskatchewan centers	37	23.3
Total - Saskatchewan	98	61.6
Alberta	2	1.3
British Columbia	3	1.9
Total - Canada	103	64.8
Florida	1	0.6
Colorado	10	6.3
Texas	4	2.5
Maryland	25	15.7
California	6	3.8
Other states	10	6.3
Total - America	56	35.2
Total	159	100.0

+Data on anglers staying at the lodges was not available.
*Local includes the community of Stony Rapids, and Eldor Mine.

The most common habitats where grayling occurred were in rapids or at the base of waterfalls that are found in northern Saskatchewan stream systems. In the rapids, grayling tended to occur on the downstream side of boulders where some protection from the current was available. Beyond the white water areas, other large fish species were common, including whitefish, suckers, walleye and pike. During the study, grayling were also captured in Wollaston Lake along the rocky shorelines of islands, and in Close Lake in the open-water area.

Examination of average fork lengths of grayling measured in some of the waterbodies revealed that size differences occurred between the populations, and these differences occurred even within the same waterbody. Although size differences are probably due in part to variations in age structure among the populations, fishing pressure can also have an effect. For example, grayling populations on the Umpherville River have suffered from increased pressure from people using the public campground since completion of the all-weather road in the 1970s. Grayling at the first rapids, immediately at the bridge crossing, are scarce. The second set of rapids on the Umpherville River is easily accessible from Highway 905 via a 0.5 km trail from the bridge crossing, whereas the third set can be accessed only by a 2 km hike through bush, or by canoe. Average size of grayling (both fork length and weight) at the second set of rapids was less than that of fish captured at the third set of rapids. This phenomenon was also noted at the Elizabeth Falls section of the Fond du Lac. Anglers staying at the

lodges at the outlet of Black Lake often walk downstream or boat over to Grayling Island for an evening of grayling fishing. The average size of grayling at Grayling Island, where most of the fishing occurs, was less than at other sites located downstream. This observation was also made during the mid-seventies on the grayling populations in the Fond du Lac (Envirocon 1974). Average fork length of grayling caught at Grayling Island during 1987 (31.6 cm) has decreased since 1973-74 when grayling averaged 33.9 cm.

At Collins Creek in the Wollaston Lake area, average size of grayling captured during the study (29.7 cm and 394 g) was greater than that of fish caught in 1979 (27.2 cm and 325 g; Saskmont 1980). This increase in size may be a result of decreased fishing pressure in the last decade. Although Collins Creek is road accessible, the main study site on the creek was inside Eldor Mine Property where public access is restricted. During the 1970s, particularly during the construction phase, employees at the mine put much pressure on the grayling populations in Collins Creek (Sawchyn 1973). Few employees had access to boats and motors necessary for fishing on Wollaston Lake, so fishing was limited to Collins Creek. Since then, two factors have caused pressure on the grayling populations to decrease: mine workers now have access to boats and motors that enable them to fish on the lake itself, and the mine currently maintains only a skeleton staff during the summer months.

Differences in condition factors between the various grayling populations are probably related to characteristics of the individual stream systems. Wollaston Lake is a large unproductive waterbody whereas the Wheeler River, lying further south, is probably more productive in terms of food organisms.

A comparison of scale ages with mean otolith ages and mean fin ray ages indicates that scales are reliable for grayling captured in the study that were up to 6 - 7 years of age. Craig and Poulin (1975) also found that both scales and otoliths of grayling gave similar results up to age 8. Age determination of grayling from scales may not be reliable for older fish, because the interpretation of annuli becomes difficult due to a reduced growth rate and consequent crowding of circuli. Thus the scale method may tend to underestimate the ages of older fish. During the study, the oldest fish sampled was 9 years of age, as determined from scales. Fish older than this may have been sampled, but because of the ageing method used, the ages may have been underestimated.

Age composition of grayling captured in the waterbodies in the study area varied. Age structure, like size, will decrease in response to exploitation. A change in age composition of grayling towards younger fish has occurred in the Fond du Lac in the last few decades. In 1955, grayling aged 7 - 10 years of age were recorded (Johnson 1971). In 1973-74, the majority of fish captured were aged 2 - 7 years, and no fish older than 7 years were recorded (Envirocon 1974).

In 1987-88, no fish were older than 6 years of age. The majority of fish were aged 2 - 4 years at Grayling Island, and 3 - 5 years at Elizabeth Falls.

In the 1970s, most grayling at Collins Creek were aged 2 years, although age classes 1 - 7 years were sampled (Saskmont 1980). During the study, fish aged 1 to 7 years and one fish age 9 years were collected. Almost equal proportion of fish aged 2 to 6 years were captured, indicating a wide range from young to old fish and a healthy population.

Age composition of grayling in other stream systems was similar to that determined for Saskatchewan grayling populations. In Little Smoky River, Alberta, grayling were aged 1 - 5 years, with classes 2 and 3 predominant (Sterling and Hunt 1989). In more northern populations, grayling appear to live longer. Grayling in the Arctic may live to be 12 years of age (Miller 1946).

Some variation in grayling size by age occurs in different Saskatchewan waterbodies, however, the range in mean length by age was usually less than 50 mm. Reasons for differences in growth rates are unknown but are probably related to characteristics of the individual stream systems such as time of break-up, temperature and food availability. Growth of grayling in Saskatchewan is similar to growth of the species in Great Bear Lake that reach 30.0 cm at age 3 and 42.3 cm by age 7 (Falk and Dahlke 1974), but faster than growth of

grayling in the Chena River in Alaska that are only 21.4 cm at age 3 years and 37.2 cm by age 7 (Roguski and Winslow 1969).

In Saskatchewan, grayling appear to reach sexual maturity at 3 - 4 years of age, when they reach 28 - 38 cm in fork length. Similar ages at maturity were determined in other studies. In the Little Smoky River in Alberta, males matured at 2 years and females at 3 years (Sterling and Hunt 1989). Age at maturity appears to occur later for more northern populations. In Great Bear Lake, maturity occurs when fish are 6 years old (Miller 1946), whereas in most systems in Alaska, the age at which most grayling mature is 4 - 8 years (Armstrong 1986). Once mature, grayling in Alaska appear to spawn every year, but during the study evidence was collected that suggests female grayling in Saskatchewan may not reproduce annually.

Rapid growth, early maturity and a short life span appear to be characteristic of the species. Maturation of fish at a smaller size in some river systems (eg. 27.0 cm in the Chena River in Alaska; Tack 1972) may be related to heavy angler harvests. Long-term harvesting of larger fish by anglers may have caused a genetic shift in the population that favours maturity at a smaller size. Inadequate data were collected on the reproductive state of graying in Saskatchewan to determine whether a shift to a younger age at maturity had occurred.

During the study, grayling in reproductive condition were captured at several areas in the Wollaston Lake area. The capture of ripe fish in Collins Creek and Umpherville River during May, 1988 was

the first evidence that grayling spawn in these two tributary streams. Previously it was thought that grayling spawned along the shores and reefs of Wollaston Lake and moved up the streams later (Saskmont 1980). Some spawning does occur in the lake itself as indicated by the observation of juvenile grayling in July, 1988 around islands not adjacent to tributaries. Grayling fingerlings were also collected in Wollaston Lake during an earlier study (Sawchyn 1973).

Preferred grayling spawning substrate is coarse sand, gravel and rock bottoms (Scott and Crossman 1973). Most of the areas studied in 1987-88 appeared to have substrate of suitable size. Spawning in tributary streams such as Collins Creek and the Umpherville River occurs before spawning in outlet streams such as the Cochrane River. In 1987, ripe grayling were captured in the Cochrane River on June 4 whereas spawning had already occurred in the other streams. In 1988, grayling in spawning condition were captured in the Umpherville River and Collins Creek between May 21-26. In the Fond du Lac at the outlet of Black Lake, spawning did not occur until June 1-10, 1988 (Calvin Parobec, manager of Morberg's Camp, pers. comm.). Factors or cues that may initiate grayling spawning are day length, threshold temperature (≈4°C) and ice breakup and subsequent run-off (Tack 1972). The latter two events would occur later in outflowing streams due to delayed ice break-up in the larger waterbodies such as Wollaston Lake.

As indicated by tag-recapture data, grayling populations in Saskatchewan remain relatively sedentary throughout the summer months.

Only 4% of the 147 grayling recaptures occurred outside the tagging area, and the maximum distance moved was 1.7 km. Travel occurred equally in an upstream and downstream direction. Similar results were found in other studies. Only 0.4% of grayling tagged in the Little Smoky River in Alberta emigrated from the catch and release area (Sterling and Hunt 1989). Greatest downstream movement was 79 km, and maximum upstream movement was 29 km. In the Chena River in Alaska, over 70% of the 136 recaptures were caught in the section of river where they were tagged (Roguski and Winslow 1969). Approximately 8% of the grayling moved upstream, and almost 20% moved downstream. All grayling recaptures were made in adjacent areas, with no grayling moving more than a few miles from the tagging point. In the Fond du Lac in 1973-76, tagged grayling exhibited very little movement as the majority of recaptures were made near the marking areas (Kratt 1977). Often an individual fish could be recaptured several times at exactly the same location over a period of months, demonstrating the sedentary nature of the species during the summer months.

Although grayling movements during the summer are not extensive, there is some evidence that the species does migrate in spring and fall to and from overwintering areas. It is unlikely that overwintering occurs in Collins Creek and Umpherville River due to the small size of these tributaries. Although no direct evidence of mass migrations was collected during the study, the capture of several grayling tagged the previous year on a single day a week after sampling

began reinforces this hypothesis. Although most grayling migrations are short, ranging from several to a dozen kilometers, grayling in Alaska may swim 130 - 160 km to reach overwintering areas (Armstrong 1986). In Saskatchewan, grayling have migrated up to 21 km in the Fond du Lac area to reach the Cree and Chipman Rivers (Envirocon 1974). During the 1987-88 study, capture of tagged grayling at their catch and release site over a year after marking suggests that grayling may return annually to a particular stream to spawn. In the Lesnica River in Poland, 18.7% of the grayling returned to spawn in their home stream (Witkowski and Kowalewski 1988).

Annual mortality rate for grayling at Elizabeth Falls on the Fond du Lac (66.9%) was similar to that determined in the 1970s (70%; Envirocon 1974) for grayling aged 5 - 7 years. Great Slave Lake grayling had a mortality rate of 65% (Gillman and Dahlke 1973). These rates are relatively high when compared to the low rate of 29.4% for grayling in Collins Creek. Differences in mortality rates can be attributed to variations in the age structure of populations, and to individual characteristics of each stream system. The high rate calculated for grayling aged 5 - 6 years at Elizabeth Falls is probably because most grayling are nearing the end of their life span by those ages.

Determining numbers of grayling in Saskatchewan waterbodies is difficult because mark-recapture studies estimate only the proportion of a population that the sampling gear is effective in capturing.

Angling, the method by which most of the grayling were captured, is effective in catching adult grayling, but few juvenile grayling were angled. Difficulties in sampling grayling were compounded because some areas of large stream systems such as the Wheeler and Geikie Rivers are not accessible to anglers. For example, the lack of older age classes in the grayling population sampled at the Wheeler River may be related to habitat preference - the older fish may live mid-stream where they are not vulnerable to angling gear. Nevertheless, in order to assess community structure and assess grayling populations in northern Saskatchewan, it is important to make estimates of population sizes.

Results obtained indicate a wide range in population sizes, from less than 100 gr yling at Jackfish Bay Creek at Close Lake to almost 25 000 at Bigstone Rapids on the Cochrane River. As previously pointed out, estimates of grayling numbers at Bigstone Rapids and the Waterfound River are probably greatly overestimated. Grayling do not appear to learn to avoid hooking from past experience, thus the same fish was probably captured and released many times, overestimating the anglers' catch and resulting population estimate. Results obtained using the Schnabel method are probably more accurate since data used incorporated only fish captured by the Fisheries Branch staff. Grayling numbers in most localities studied in Saskatchewan were less than 5 000. In contrast, the largest numbers of grayling found in any one location in Alaska was in a stream between Long Tangle and Lower Tangle Lakes where an estimated 36 935 fish occur (Roguski and Tack 1970). Estimates

for the Chena River at two difference sections were 1 357 and 3 286 grayling (Roguski and Winslow 1969).

Any long-term trends in abundance of grayling in Saskatchewan can be determined only for the Fond du Lac at the outlet of Black Lake. An earlier study carried out in the area in 1973-74 estimated grayling numbers at Grayling Island to be 7 776, and at Elizabeth Falls, 5 269 (Envirocon 1974). Estimates for the same two areas for 1987 was 5 024 and 3 844, respectively. Although numbers were less in the present study than in the 1970s, the difference is not significant ($p < 0.05$). This is not unexpected considering the area is accessible only by aircraft: angling pressure has probably not changed substantially in the last few decades. According to rates of exploitation, pressure on the grayling population has decreased in recent years. In the 1970s, rate of exploitation in the Fond du Lac was estimated at 15% (Envirocon 1974) whereas it was 8.6% at Grayling Island and 4.6% at Elizabeth Falls in 1987.

Although no hard data are available to determine trends in the grayling fishing at other locations in Saskatchewan, reports from outfitters indicate that grayling fishing has declined during the last few decades. Jack O'Brien, owner of Careen Lake Lodge, revealed that the grayling fishing at the outlet of Careen Lake has deteriorated over the last 30 years (pers. comm.). Increased pressure comes from anglers flying in from Alberta, and from canoeists using the Clearwater River in the newly developed wilderness park. Success rate of Careen Lake

anglers was among the poorest recorded for the province, at 0.5 fish/angler-hr.

The size of a population in any one area is dependant on a number of factors: size of waterbody and available grayling habitat, suitable spawning areas, food availability, % cover (including boulders in the stream and overhanging vegetation), as well as angler usage. Grayling populations in the Fond du Lac at Elizabeth Falls (3 844) are relatively larger than found in Collins Creek (726), however the Fond du Lac is a much larger water system. The rapids at Elizabeth Falls extend for approximately 3 km whereas at Collins Creek in the vicinity of the pumphouse, the rapids are only about 0.5 km in length.

Exploitation of the various populations also affects size structure. Rate of exploitation was highest at the Umpherville River at 9.0%. This stream is road accessible and receives high angling pressure from campers using the public campground located at the highway crossing. The first set of rapids, located at the campground, now supports a minimal grayling population as no grayling were captured there by the Fisheries Branch staff. According to local residents, grayling were more abundant at these rapids in the past. A similar situation has occurred in the Geikie River. This river also receives angling pressure from campers at the public campground, canoeists and cabin owners along the river. Very few grayling are now captured at the first set of rapids, although they were plentiful there in the past (John Tinline, angler, pers. comm). The second set of rapids, which

requires a long portage to reach, supports a better grayling population, but the best fishing occurs further upstream where the Wheeler and Geikie Rivers join (Dick Cossette, local outfitter, pers. comm.). Access to these rapids is mainly fly-in.

High rates of exploitation are apparent in angler success rates. Success rates at the Umpherville and Geikie Rivers were among the poorest for grayling fishing recorded in the province. The higher success rates at the more remote, fly-in locations are probably due to a number of reasons, including lower fishing pressure, use of expert guiding services, and the catch and release policy that many northern outfitters impose.

4.2 MANAGEMENT CONSIDERATIONS

In Saskatchewan, grayling have been exploited primarily by the sport fishery and secondarily by the domestic fishery. Commercial fishermen capture grayling only incidentally in their gillnet sets.

Although not considered to be a big Saskatchewan gamefish species as are pike, walleye and lake trout, grayling add to the excitement of sport fishing in the province. They are one of the few native species that can be readily taken by a fly. The presence of a nearby grayling population is a factor clients consider when choosing a northern lodge for a fishing trip. Many guests enjoy an evening of fly fishing after a day spent out on the lake. Because grayling usually

live in sheltered riverine environments, guests may fish for this species when inclement weather prevents open-water fishing trips.

The tendency of grayling to occur in isolated 'pockets' plus an attraction to artificial lures makes the species particularly vulnerable to being overfished. Grayling populations in certain areas of the province have deteriorated over the last few decades, as indicated by a decrease in size and age composition and by the scarcity of grayling at areas where they used to be common. Populations at road accessible locations have particularly been affected, but grayling at more remote, fly-in locations are also showing signs of overexploitation. Therefore, it is feasible to implement a management strategy to protect the species.

Grayling are not known for their eating quality, especially after being frozen. Therefore there is little incentive for anglers to harvest large numbers of this species for home use. Resident anglers of Uranium City, Camsell Portage and Stony Rapids, however, do enjoy eating fresh grayling and catch them for domestic consumption. Whitefish, lake trout, walleye and pike occur in areas adjacent to the grayling 'holes' on the Fond du Lac River, therefore alternative fish species are available that could be utilized as a food source.

The major user group, northern outfitters, would like to see conservation measures implemented for grayling. A survey distributed to outfitters in July, 1986 revealed that the majority of respondents favoured a reduced limit. Many outfitters are already setting limits on

the numbers of grayling harvested by their guests by promoting grayling as a 'catch and release' species. Most outfitters would like to see a reduction to 1 grayling per day from the current daily limit of 5 fish. However, a reduction to 2 fish per day would permit an angler to continue fishing after 1 grayling had been taken for a trophy or shore lunch. With this reduction, resident anglers could still use grayling as a food source, although they should be encouraged to focus their efforts on alternative fish species.

The current limit for grayling in Saskatchewan states that only 1 fish over 1 kg can be harvested daily. This upper size limit protects only 5% of the population. Because grayling in Saskatchewan do not appear to spawn every year, it is important to protect a higher percentage of the spawning stock. By lowering the size limit so that only 1 fish over 30 cm may be harvested, the majority of the spawning grayling stock would be protected.

The use of barbless hooks and flies is encouraged at many northern lodges. More anglers will follow this practice if it is made a regulation rather than a suggestion. During the study, barbless hooks were employed exclusively and were effective in capturing grayling. Use of barbless hooks and flies reduces the delayed mortality of grayling after fish are caught and released, because a fish caught on a barbless hook can be released much more quickly than one caught on a barbed hook. This results in less handling time and thus reduced stress to the fish.

Even with the use of barbless lures, there is still some mortality involved when large numbers of grayling are caught and released. As suggested in the Angler's Guide, anglers should estimate their total fish kill in order to know when to stop fishing.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

1. A two year study of Arctic grayling was carried out during the summers of 1987 and 1988 in northern Saskatchewan. During the study, grayling were investigated at three areas in the province: Wollaston Lake area, Fond du Lac area and Clearwater River area. Several waterbodies within each of these locations were examined.
2. Adult grayling were captured using hoopnets, gillnets and angling gear. Over 90% of the fish were caught by angling. Barbless hooks and flies were used. Estimated angling mortality (short-term) was 1.9%. Juvenile grayling were captured with a seine net, lift net and fry net.
3. Grayling are distributed in the northern third of Saskatchewan as far south as the 56th parallel, although they have been stocked successfully in more southern waterbodies. Their natural habitat consists of clear, northern rivers and streams where swift flowing waters and rapids abound, and along the rocky shorelines and islands of northern lakes.

4. Grayling occur in localized 'pockets' and this tendency, plus an attraction to artificial lures, makes the species particularly vulnerable to being overfished.

5. A mark-recapture study was carried out to estimate grayling populations. A total of 1 140 grayling were tagged during the two years, and 147 recaptures have been made (12.9%). Rate of tag loss was estimated at 12.5%. The majority of recaptures occurred at the tagging site. Only 6 grayling moved from one location to another, and maximum distance travelled was 1.7 km.

6. Grayling captured during the survey ranged in size from 8.1 to 46.0 cm in fork length. Average fork lengths varied from 22.3 cm at Jackfish Bay Creek on Close Lake to 37.9 cm at Middle Lake inlet on the Fond du Lac. Average weights ranged from 172 g at Jackfish Bay Creek to 582 g at the third set of rapids on the Umpherville River. Condition of grayling sampled at the various locations varied significantly, with fish from the Wheeler River being more robust than fish captured elsewhere.

7. Ages of grayling captured during the study ranged from 1 to 9 years, based on scale samples. Age composition of the grayling varied, depending on location. On the Fond du Lac, most grayling were aged 3 - 5 years whereas in the Wheeler River, most grayling were younger than 3 years. Grayling

captured in the Fond du Lac and Clearwater River systems achieved a larger size at age than those in other waterbodies examined.

8. Grayling reproduction in Saskatchewan occurs between mid-May and mid-June, depending upon the arrival of spring and subsequent ice break-up. Grayling in spawning condition were captured in Collins Creek and Umpherville River in the Wollaston Lake area between May 21-26, 1988.

9. Spawning occurred in areas where water depths were less than 2 m, and the substrate was gravel, rubble and boulder. Grayling eggs were collected in this bottom material adjacent to shore in the backwater areas of the rapids. Such habitat is often formed in spring by ice break-up and flooding.

10. Grayling in reproductive condition ranged between 3 - 9 years in age. Age at maturity appears to occur when grayling are 3-4 years of age, at 28 - 38 cm in fork length. Average fork length of spawning fish was 35.9 cm for females and 34.0 cm for males. Examination of grayling gonads in spring indicated that some females contained immature eggs. This suggests that grayling probably do not spawn every year.

11. Young grayling rely mainly on chironomids as a food source in June and July but by August, Trichoptera (caddisfly larvae) were the major food item ingested.

12. Adult grayling rely mostly on aquatic insects for their diet, and overall, caddisflies were the dominant insect consumed. Other organisms important to grayling as a food source were mayflies and aquatic bugs. Lake-dwelling grayling ate mainly terrestrial organisms such as beetles, wasps, grasshoppers and spiders.

13. Mortality rates of grayling older than 2 years varied between 29.4% at Collins Creek and 66.8% at Elizabeth Falls on the Fond du Lac.

14. Population estimates derived from the mark-recapture experiment ranged from 91 grayling at Jackfish Bay Creek on Close Lake to 24 588 at Bigstone Rapids on the Cochrane River. Estimates for Umpherville River and Collins Creek, two road accessible sites, were 225 and 726 grayling, respectively.

15. Grayling are exploited primarily by the sport fishery and secondarily by the domestic fishery. Commercial fishermen capture grayling only incidentally in their gillnet sets. No quantification of the grayling harvested by the domestic fishery was made.

16. Rates of exploitation by anglers on the various grayling populations in the province ranged from 1.1% at Careen Lake to 9.0% at the Umpherville River.

17. An estimated 3 782 angler-hr were spent fishing for grayling in the study area. Anglers captured almost 10 000 grayling, but kept less than 10% of their catch. Angler success varied from a minimum of 1.1 fish/angler and 0.2 fish/angler-hr on the Geikie River to a maximum of 25.7 fish/angler and 6.1/angler-hr at the Waterfound River. Success tended to be better at the more remote fly-in locations than at road accessible sites.
18. Numbers of grayling kept by anglers varied from 3.7% of their total catch at Grayling Island on the Fond du Lac to 90.8% on the Geikie River.
19. The majority of anglers (≈85%) stayed in northern lodges during their fishing trip. Most anglers (83.8%) were aged 21-64 years. Male anglers outnumbered females by almost 10:1.
20. Over 60% of the anglers contacted were Saskatchewan residents. Other Canadians comprised less than 5% of the anglers while Americans represented 35.2% of the angling population. However, data on the anglers staying at northern fishing lodges were not included in these estimates.

5.2 RECOMMENDATIONS

1. Reduce grayling limits to 2 fish per day (4 in possession), with only 1 fish to exceed 30 cm in fork length. Such a

reduction will help protect grayling stocks while still allowing northern residents to use grayling as a food source. Informing anglers that grayling do not freeze well will discourage fishermen from keeping grayling. A statement in the angler's guide should suffice.

2. Use of barbless hooks should be mandatory when anglers are grayling fishing, thereby reducing mortality of fish that have been caught and released.
3. A re-evaluation of the status of grayling populations in northern Saskatchewan should be undertaken in 5 - 10 years to assess the impact of present management strategies.

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Appendix 1. Number and species of fish caught during the study period, 1987 and 1988.

1987	Location		Method of capture	Number of fish captured: grayling	others*
May 21-June 8	Collins Ck	-pumphouse	hoopnet	7	2 BU; 22 CWS; 541 LNS; 5 WF
			angling	57	
			gillnet	1	
		-borrow pit	hoopnet	1	2 BU; 3 CWS; 1573 LNS
			angling	0	
		-downstream from Kewen L	angling	1	2 NP
	Umpherville R	-1st rapids	angling	0	
		-2nd rapids	angling	15	1 WF
			gillnet	0	
		-3rd rapids	angling	29	1 WF
			gillnet	1	
	Geikie R	-1st rapids	angling	0	
			gillnet	0	
		-2nd rapids	angling	0	4 NP
	Cochrane R	-Bigstone Rapids	angling	59	
	Wollaston L	-Collins Bay	gillnet	0	24 NP; 6 WF; 2 LT
		-Parker Island	gillnet	3	
		-Harrison Peninsula	gillnet	3	1 LNS; 1 WF
June 25-28	Geikie R	-1st rapids	gillnet	0	4 NP; 2 LNS
			angling	0	3 NP
			minnow trap	0	1 dace
		-2nd rapids	angling	4	
			minnow trap	0	1 trout-perch
			lift net	10	
June 29-July 8	Fond du Lac	-Grayling Island	angling	120	
			fry net	8	
		-Elizabeth Falls	angling	114	
			fry net	1	
		-Middle Lake inlet	angling	113	

			fry net	0	
		-Woodcock Rapids	angling	10	
	Black L	-Dog Island	gillnet	0	10 CWS; 7 NP; 2 WF
		-Fir Island	gillnet	0	39 CWS; 6 NP; 2 WF
	Grease R		angling	28	
	Chipman R		angling	43	
July 23-27	Blackbirch R	-Careen L outlet	angling	93	
			fry net	0	
July 28-29	Clearwater R	-Lloyd L outlet	angling	13	
			fry net	0	1 YW
Aug 17-23	Geikie R	-1st rapids	angling	0	
	Collins Ck	-pumphouse	angling	26	
		-downstream of Kewen L	angling	5	
			gillnet	0	5 NP; 4 WF; 2 YW
			fry net	0	
	Umpherville R	-2nd rapids	angling	0	1 NP
			fry net	0	
		-3rd rapids	angling	4	
	Wollaston L	-Ivison Bay	gillnet	0	1 BU; 2 LNS; 1 WF
		-Harrison Peninsula	gillnet	0	5 LT; 1 WF
1988					
May 16-26	Collins CK	-pumphouse	hoopnet	6	1 CWS; 37 LNS 1 NP; 2 WF; 3 YW
			angling	63	
		-airport	hoopnet	0	1 NP; 50 LNS; 2 WF
		-upstream of 2nd bridge crossing, Pts N Rd	angling	1	
		-downstream of 2nd bridge crossing, Pts N Rd	angling	1	
		-downsteam of Kewen L	angling	2	
	Umpherville R	-1st rapids	angling	0	
		-2nd rapids	angling	0	
			gillnet	0	2 LNS; 2 WF
		-3rd rapids	angling	10	

June 8-19	Collins CK	-pumphouse	angling	56	
		-downstream of Kewen L	angling	1	
		-upsteam from 2nd bridge crossing, Pts N Rd	angling	1	
	Umpherville R	-3rd rapids	angling	8	
	Geikie R	-1st rapids	angling	0	
		-2nd rapids	angling	3	
	Wollaston L	-Harrison Peninsula	gillnet	0	12 WF
		-Parker Island	gillnet	0	1 BU; 2 LNS; 6 WF
	Waterfound R		angling	6	
July 8-12	Close L	-Jackfish Bay	gillnet	0	1 NP; 2 LNS; 2 WF
		-Jackfish Bay CK	angling	56	
		-Yalowega R	gillnet	2	2 NP; 7 LNS; 16 WF
			angling	114	
			gillnet	0	
			fry net	0	
July 15-19	Wheeler R	-1st rapids upstream	angling	36	
		-2nd rapids upstream	angling	13	
		-1st rapids downstream	angling	16	
			fry net	1	
			lift net	10	
Aug 3-8	Clearwater R	-rapids 0.5 km upstream of Hwy 955 bridge	angling	5	
		-Mackie Rapids	angling	12	
			fry net	0	
		-rapids downstream of Warner rapids	angling	3	
			fry net	0	
Aug 15-21	Collins Ck	-pumphouse	angling	24	
			fry net	0	
		-downstream of Kewen L	angling	9	
			fry net	2	1 NP
	Umpherville R	-2nd rapids	angling	7	
			fry net	3	

	-3rd rapids	angling	10	
		fry net	5	1 YW
Geikie R	-1st rapids	angling	0	
	-2nd rapids	angling	3	
Wollaston L	-Whisky Pt	gillnet	2	4 CWS; 44 LNS
	-Parker Island	gillnet	13	22 LNS; 2 WF
		fry net	0	
	-North Island	angling	2	
		gillnet	3	7 CWS; 81 LNS

* BU-burbot; CWS-white sucker; LNS-longnose sucker; NP-northern pike; WF-whitefish; YW-yellow walleye

Appendix 2. Record of water analyses from grayling waters in northern Saskatchewan in 1987 and 1988. All results are expressed in $mg.L^{-1}$, except pH.

	Collins Creek					Umoherville River				
	08-06-87	20-08-87	26-05-88	18-06-88	20-08-88	07-06-87	19-08-87	25-05-88	19-06-88	20-08-88
Chloride	3.55	3.37	6.20	6.91	7.27	3.37	2.84	6.74	7.45	7.09
Calcium	4.92	2.38	4.21	3.49	2.86	4.05	10.60	29.22	3.02	2.54
Alkalinity -total	20.2	11.7	5.3	6.6	7.9	16.3	5.7	-	8.4	6.8
TDS	24	27	20	25	13	23	45	64	18	32
pH	7.25	7.00	6.89	6.90	6.99	7.01	7.35	8.42	6.90	6.98

	Gaikie River			Wollaston L.		Waterfound R.	Yalowega R.	Wheeler R.
	28-06-87	23-08-87	16-08-87	17-06-88	17-08-88	18-06-88	12-07-88	19-07-88
Chloride	2.30	2.13	6.91	7.98	6.74	5.85	6.74	5.32
Calcium	4.61	3.49	4.37	3.97	3.81	3.26	3.81	5.40
Alkalinity -total	11.5	9.7	9.9	9.7	10.6	8.7	8.5	7.7
TDS	24	25	20	24	13	7	9	28
pH	7.10	7.20	7.02	7.12	7.42	7.03	7.16	7.01

	Clearwater River			
	Careen L. 27-07-87	Lloyd L. 29-07-87	Hwy 955 08-08-88	Fond du Lac 08-07-87
Chloride	2.67	2.84	7.27	4.61
Calcium	3.02	5.00	5.48	4.05
Alkalinity -total	11.1	12.5	13.0	10.8
TDS	27	40	34	33
pH	7.24	7.15	7.21	7.14

Appendix 3. Composition of the channel substrate of the Umpherville River on August 19, 1987.

I	Interval	12" cross-section	Classification*
	1 ft	10" lg boulder, 2" rubble	1 ft lg boulder
	2	12" lg boulder	1 ft lg boulder
	3	12" lg boulder	1 ft lg boulder
	4	12" small boulder	1 ft sm boulder
	5	9" small boulder 3" sediment	1 ft sm boulder
	6	11" rubble; 1" sediment	1 ft rubble
	7	12" rubble	1 ft rubble
	8	4" small boulder 8" rubble	1 ft rubble
	9	12" lg boulder	1 ft lg boulder
	10	12" rubble	1 ft rubble
			Total = 4 ft lg boulder 2 ft sm boulder 4 ft rubble
II	1	10" rubble; 2" sediment	1 ft rubble
	2	10" rubble; 2" sediment	1 ft rubble
	3	6" small boulder; 6" rubble	1 ft small boulder
	4	5" small boulder; 3" sediment; 4" rubble	1 ft small boulder
	5	12" lg boulder	1 ft lg boulder
	6	12" rubble	1 ft rubble
	7	10" rubble; 2" gravel	1 ft rubble
	8	6" rubble; 6" gravel	1 ft rubble
	9	4" sm boulder; 3" rubble; 5" gravel	1 ft gravel
	10	12" rubble	1 ft rubble
			Total = 1 ft lg boulder 2 ft sm boulder 6 ft rubble 1 ft gravel

*Classification (Platt et al. 1983):

particle diameter size largest diam), in.	sediment classification
≥ 24.0	large boulder
12.0 - 23.9	small boulder
3.0 - 11.9	rubble (cobble)
0.19 - 2.9	gravel
0.033 - 0.18	fine sediment - large
≤ 0.032	fine sediment - small

Appendix 4. Organisms collected by drift net at various locations in northern Saskatchewan in 1987.

	Collins Creek			Umpherville River			Geikie River			Fond du Lac		Careen L.	Lloyd L.
	May 25	June 1	Aug 19	May 25	May 31	Aug 18	May 26	June 27	Aug 23	June 30	July 7	July 25	July 29
Ephemeroptera													
Baetidae		5											
Baetis	8	2	4		1	2	2		2		4		2
Ephemerellidae													
Drunella	4	3	1								1		
Ephemerella	1												
Eurylophella loda					1				1				
Heptageniidae													
Stenonema			1										
Hymenoptera							1						
Trichoptera-unidentified			1								1		
Brachycentridae													
Brachycentrus	11	14	9		1								
Glossosomatidae													
Glossosoma									1				
Hydropsychidae													
Cheumatopsyche		2	1				1						
Hydropsyche	1	5	1		5	2	1		5	1	1		2
Lepidostomatidae													
Lepidostoma	1	4	3										
Leptoceridae													
Triaenodes		2											
Limnephilidae							2						
Diptera													
Chironomidae	60	82	27	36	370	14	10	28	20	63	95		1
Dolichopodidae	1												
Empidae	1	3			1								
Simuliidae	6	54	6	2	25	3	21	1	14	17			
Hirudinea						1							
Total Number	94	176	54	38	404	22	38	29	43	81	102	0	5

Appendix 5. Organisms collected by sweep net at various locations in northern Saskatchewan in 1987.

	Collins Creek			Umpherville River			Geikie River			Fond du Lac		Careen L.	Lloyd L.
	May 25	June 1	Aug 19	May 25	May 31	Aug 18	May 26	June 27	Aug 23	June 30	July 7	July 25	July 29
Coleoptera													
Dytiscidae													
Hydaticus											1		
Ephemeroptera													
Baetidae			1										
Baetis		4		3	5	2	9		1	3			
Baetiscidae													
Baetiscus							3		2				
Caenidae													
Caenis												1	
Ephemerellidae													
Attenella													2
Drunella	46	57	2	7	3		1	2					
Ephemerella	8	4		16	4		1	9					
Eurylophella loda							5	2					
Ephemeridae													
Ephemera							1					1	
Heptageniidae													
Heptagenia	1			24	8	11	13	10	37				
Stenonema	19	10	13	34	13	4	8	23	64			5	2
Leptophlebiidae													
Leptophlebia				2	6								
Paraleptophlebia	13	6		6	34		23		8				
Tricorythidae													
Tricorythodes													2
Hemiptera													
Corixidae								1					
Sigara	2												
Odonata													
Cordullidae													
Somatochlora						1	4						

Gomphidae																		
Ophiogomphus	6	1	16		3	31	5	59	45							5		
Plecoptera-unidentified								1										
Leuctridae																		
Leuctra ferruginea					1													
Perlidae																		
Acroneuria abnormis			1	1														
Acroneuria lycorias	1					4		1	1							6		
Claussenia sabulosa	2	1	13						1									
Perlodidae	3																	
Isogenoides	8		14	3		18			3									
Isoperla bilineata							9											
Isoperla transmarina					8													
Isoperla		2		7														
Pteronarcidae																		
Pteronarcys dorsata				3		17												
Trichoptera																		
Brachycentridae																		
Brachycentrus	60	249	598	39		4												
Hydropsychidae																		
Cheumatopsyche		3	2					1	3									
Hydropsyche	25	24	17	54	2	20	1	1	8	1						73		
Lepidostomatidae																		
Lepidostoma		12	66	8	2			13								16		
Leptoceridae																		
Ceraclea	3	4		2			5	11								23		
Mystacides								31										
Limnephilidae														1				
Halesochila											11							
Limnephilus																1		
Onocosmoecus				16												2		
Philopotamidae																		
Chimarra			1					1	34									
Phryganeidae																		
Agrypnia							1											
Polycentropidae																		
Neureclipsis			1	1					20									
Rhyacophilidae																		
Rhyacophila	1			2	1													

Diptera													
Chaoboridae										1			
Chironomidae	4	13	30	34	6	1	2	4	80	95	17	2	
Culicidae										1			
Ephydridae			1										
Simuliidae		1					1	6	3				
Amphipoda													
Hyalella											33	27	
Oligochaeta								2			9		
Hirudinea			4	1		1					10	260	
Gastropoda							2	1	4	3	1	1	
Sphaeriidae						9	3	12					
Total	202	391	780	263	96	123	97	171	252	92	111	78	422

Appendix 6. Organisms collected by Surber sample at various locations in northern Saskatchewan in 1987.

	Collins Creek			Umpherville River			Geikie River			Fond du Lac		Blackbirch R.	Clearwater R.
	May 25	June 1	Aug 19	May 25	May 31	Aug 18	May 26	June 27	Aug 23	June 30	July 7	July 25	July 29
Coleoptera													1
Elmidae					1								
Dytiscidae												1	
Ephemeroptera													
Baetidae			1						2				
Baetis				5	6					1			
Pseudocloeon								1					
Ephemeridae													
Ephemera							2						
Ephemerellidae													
Drunella	2												
Ephemerella				1	1								
Eurylophella				1			2						
Attenella													1
Heptageniidae													1
Heptagenia					1					2			
Stenonema		15	1	1	3	2			5			1	
Leptophlebiidae	2	1				2							
Leptophlebia										1			
Paraleptophlebia						1	1						1
Tricorythidae													
Tricorythodes													1
Odonata													
Gomphidae													
Ophiogomphus						3			2				
Libellulidae							1						
Plecoptera			1										
Nemouridae													
Nemoura	1												
Perlidae						1							
Acroneuria abnormis													3
Acroneuria lycorias													1
Perlodidae									1				
Isogenoides	12					1				2			
Isoperla				2	1								
Isoperla bilineata								1					

Trichoptera- unidentified													1					
Brachycentridae																		
Brachycentrus	1																	
Glossosomatidae																		
Glossosoma			1															
Hydropsychidae																		
Hydropsyche	3	1			4	1			32	1				14				
Cheumatopsyche						1		5	60									
Hydroptilidae																		
Hydroptila										1								
Lepidostomatidae			1			1								7				
Leptoceridae								4										
Ceraclea			3											2				
Oecetis					2													
Nectopsyche			2															
Limnephilidae					1													
Ecclisomyia			1		1													
Limnephilus														6				
Philopotamidae																		
Chimarra									30									
Polycentropodidae																		
Neureclipsis									2									
Rhyacophilidae									1									
Diptera																		
Chironomidae		2	27	15		1	1	3	1	41	3	6		3				
Empidae																		
Hemerodromia			1					1										
Simuliidae				1		1			1									
Nematoda								1										
Hirudinea														13				
Oligochaeta							1											
Gastropoda										1	3			1				
Sphaeriidae				4	4	43	3	2			7							
Amphipoda																		
Gammarus														1				
Total	21	19	39	30	25	58	11	18	137	50	13	9		56				
Wet wt, g	1.52	0.70	0.12	0.13	0.36	0.84	0.23	0.10	1.30	0.44	0.12	0.04		2.68				

Appendix 7. Organisms collected by sweep net at various locations in northern Saskatchewan in 1988.

	Collins Creek					Umpherville River					Geikie River		Yalowega	Clearwater R.
	May 19	May 25	June 8	June 15	Aug 21	May 20	May 25	June 8	June 15	Aug 20	June 9	Aug 16	July 10	Aug 8
Ephemeroptera-unidentified								1						
Baetidae														
Baetis	2		4	3	3		2	3	7					10
Pseudocloeon										1		1		2
Caenidae														
Caenis														4
Ephemerellidae														
Attenella												1		2
Drunella	4	15	48	17	4		2	1					7	16
Ephemerella	11	3	2	3	2	2	12	5	7	4	2			1
Eurylophella	1					3	1	9	3		1			
Seratella					1									
Ephemeridae														
Ephemera												1		
Heptageniidae														
Heptagenia	4				4		3	1	5	29	1	24		6
Stenonema	3	10	6	7	32	2	5	3	3	7	1	3		4
Leptophlebiidae														
Leptophlebia	3					1	1	1	1					
Paraleptophlebia	2	2	4	1			2		3	2	6			
Lepidoptera														
Cossidae		1												
Odonata														
Gomphidae														
Ophiogomphus			2	1	18			1			4	24		29
Plecoptera														
Nemouridae														
Nemoura	11	1				14	18							
Zapata										3				
Perlidae														
Claassenia					5									1

Perlodidae																		
Isogenoides			2		13		3			11								
Isoperla	2	3	3	1		4		3			1		1					
Pteronarcidae																		
Pteronarcys																		
Trichoptera-unidentified																	13	
Brachycentridae													1					
Brachycentrus	2	29	85	36	25	1		1	6	2			41				3	
Glossosomatidae																		
Glossosoma					4													
Hydropsychidae																		
Hydropsyche	6	9	9	1	15	1	2	1	2	9		2	3				19	
Cheumatopsyche					3					2		2					4	
Hydroptilidae																		
Hydroptila																	1	
Lepidostomatidae																		
Lepidostoma	1	26	43	87	81				7	2	2		4					
Leptoceridae																		
Ceraclea		1	3	7	1				3			1						
Mystacides					1													
Oecetis																	1	
Limnephilidae									3									
Limnephilus					2													
Onocosmoecus							7	4					25					
Philopotamidae																		
Chimarra												4					40	
Phryganeidae																		
Fabria										1								
Polycentropidae																		
Neureclipsis										26		11						
Rhyacophilidae																		
Rhyacophila							1											
Diptera																		
Ephydridae																		
Chironomidae	8	14	18	10	5	2	4	5	8	27	3	3	1 9				36	
Culicidae					1													
Simuliidae				32	5			2	20		5						48	
Hirudinea					2					1								

Oligochaeta											1					1		
Gastropoda							1						1	4				
Sphaeriidae					1			3	1	3	3	6	20	7		95		
Total Number	60	114	229	206	228	31	66	41	82	131	32	99	103	336				

Appendix 8. Organisms collected by Surber sampler at various locations in northern Saskatchewan in 1988.

	Collins Creek					Umpherville River					Geikie River		Yalowega	Wheeler R.	Clearwater R.
	May 19	May 25	June 8	June 15	Aug 21	May 20	May 25	June 8	June 15	Aug 20	June 9	Aug 16	July 10	July 19	Aug 8
Coleoptera															
Elmidae															
Cleptelmis	1														
Ephemeroptera															
Baetidae															
Baetis		3	29	5	1						2	1			1
Pseudocloeon													1		
Ephemerellidae															
Drunella	1		5	3											2
Ephemerella	1	1	2												
Eurylophella							1	1					1	3	
Seratella														4	1
Heptageniidae															
Heptagenia										1		1		2	
Stenonema			1		2		1								1
Leptophlebiidae															
Paraleptophlebia	10	7	11	1	1	1		1				2		2	
Hemiptera															
Corixidae						1									
Odonata															
Gomphidae															
Ophiogomphus			1	2								2			3
Plecoptera															
Nemouridae															
Nemoura rickeri						3									
Perlodidae															
Isogenoides	4	2	2		2					2		1		5	
Isoperla			5												
Pteronarcidae															
Pteronarcys dorsata															3

Appendix 8 Continued

Trichoptera																		
Brachycentridae																6		
Brachycentrus			3	2														
Glossosomatidae																		
Glossosoma												1						
Hydropsychidae																		
Hydropsyche	2	1	7	4			1			16		7				46		1
Cheumatopsyche		1						1		4		20				6		
Lepidostomatidae																		
Lepidostoma	1	4		1	8			1										
Leptoceridae																		
Ceraclea		1			22			3	2	3	1	2				2		
Oecetis																	2	
Limnephilidae																		
Limnephilus			1					2										
Philopotamidae																		
Chimarra												2					1	
Polycentropidae																		
Neureclipsis										22		4						
Rhyacophilidae																		
Rhyacophila										1		1						
Diptera																		
Chironomidae	4	18	29	10	2		1	1	15	10	6	3	4	8		10		
Simuliidae			485	375					3	45		1						
Hirudinea					5			2	2					1				1
Oligochaeta					1						2					6		
Gastropoda					26								1	1		3		
Sphaeriidae					46		3	6	9	8	3	2	18	12		14		7
Total Number	24	38	581	403	116		9	12	38	65	60	9	67	24		109		23
Wet weignt, g	0.57	0.24	1.63	2.16	0.31		0.04	0.17	0.14	0.14	0.32	0.05	0.59	0.09		0.57		0.66

Appendix 9. Grayling recaptures in northern Saskatchewan, 1987 - 1988.

Tagging location	Tagging date	Tag no.	Recapture location	Recapture date	Total days	Dist km*	Method of capture
Collins Ck	-	-	Collins Ck	26-05-88	-	0	Fisheries
Collins Ck	19-08-87	1244	Collins Ck	18-06-88	303	0	Fisheries
Collins Ck	19-08-87	1245	Collins Ck	14-06-88	299	0	Fisheries
Collins Ck	21-08-87	1266	Collins Ck	19-08-88	363	0	Fisheries
Collins Ck	05-06-87	1603	Collins Ck	28-07-87	54	0	Angler
Collins Ck	05-06-87	1607	Collins Ck	07-06-87	2	0	Fisheries
Collins Ck	05-06-87	1612	Collins Ck	24-05-88	353	0	Fisheries
Collins Ck	23-05-87	1909	Collins Ck	02-06-87	10	0	Fisheries
Collins Ck	24-05-87	1922	Collins Ck	05-06-87	12	0	Fisheries
Collins Ck	24-05-87	1922	Collins Ck	27-07-87	65	0	Angler
Collins Ck	24-05-87	1923	Collins Ck	01-06-87	8	0	Fisheries
Collins Ck	01-06-87	1946	Collins Ck	14-06-88	378	0	Fisheries
Collins Ck	01-06-87	1946	Collins Ck	24-05-88	357	0	Fisheries
Collins Ck	01-06-87	1952	Collins Ck	24-05-88	357	0	Fisheries
Collins Ck	01-06-87	1954	Collins Ck	14-06-88	378	0	Fisheries
Collins Ck	01-06-87	1954	Collins Ck	12-06-88	376	0	Fisheries
Collins Ck	01-06-87	1954	Collins Ck	26-05-88	359	0	Fisheries
Collins Ck	02-06-87	1957	Collins Ck	05-06-87	3	0	Fisheries
Collins Ck	02-06-87	1958	Collins Ck	03-06-87	1	0	Fisheries
Collins Ck	02-06-87	1959	Collins Ck	05-06-87	3	0	Fisheries
Collins Ck	02-06-87	1961	Collins Ck	05-06-87	3	0	Fisheries
Collins Ck	03-06-87	1981	Collins Ck	05-06-87	2	0	Fisheries
Collins Ck	12-06-88	2378	Collins Ck	14-06-88	2	0	Fisheries
Collins Ck	12-06-88	2379	Collins Ck	14-06-88	2	0	Fisheries
Collins Ck	12-06-88	2379	Collins Ck	14-06-88	2	0	Fisheries
Collins Ck	12-06-88	2384	Collins Ck	14-06-88	2	0	Fisheries
Collins Ck	12-06-88	2385	Collins Ck	18-06-88	6	0	Fisheries
Collins Ck	12-06-88	2386	Collins Ck	14-06-88	2	0	Fisheries
Collins Ck	18-06-88	2391	Collins Ck	26-06-88	8	0	Angler
Collins Ck	21-05-88	2402	Collins Ck	20-08-88	60	0	Fisheries
Collins Ck	21-05-88	2402	Collins Ck	14-06-88	24	0	Fisheries
Collins Ck	21-05-88	2405	Collins Ck	06-07-88	47	0	Angler
Collins Ck	08-06-88	2435	Collins Ck	14-06-88	6	0	Fisheries
Collins Ck	18-06-88	2447	Collins Ck	04-07-88	16	0	Angler
Collins Ck	23-05-88	2451	Collins Ck	12-06-88	20	0	Fisheries
Collins Ck	23-05-88	2451	Collins Ck	14-06-88	22	0	Fisheries
Collins Ck	26-05-88	2471	Collins Ck	18-06-88	23	0	Fisheries

Appendix 9 continued

Collins Ck	18-05-88	2482	Collins Ck	24-05-88	6	0	Fisheries
Collins Ck	20-05-88	2495	Collins Ck	26-05-88	6	0	Fisheries
Collins Ck	19-08-88	2907	Collins Ck	21-08-88	2	0	Fisheries
		?	Umpher-3rd	---06-88	-	0	Angler
Umpher-2nd	07-06-87	1633	Umpher-3rd	23-07-87	46	-1.7	Angler
Umpher-2nd	07-06-87	1634	Umpher-1st	15-07-87	38	+0.5	Angler
Umpher-2nd	22-05-87	1908	Umpher-2nd	08-06-88	17	0	Fisheries
Umpher-2nd	21-05-87	1993	Umpher-3rd	23-07-87	63	-1.7	Angler
Umpher-2nd	21-05-87	1994	Umpher-3rd	08-06-88	383	-1.7	Fisheries
Umpher-2nd	21-05-87	1995	Umpher-1st	16-07-88	421	+0.5	Angler
Umpher-2nd	22-05-87	1999	Umpher-2nd	05-06-87	14	0	Fisheries
Umpher-3rd	08-06-87	1636	Umpher-3rd	08-06-88	365	0	Fisheries
Umpher-3rd	08-06-87	1638	Umpher-3rd	23-07-87	45	0	Angler
Umpher-3rd	24-05-87	1926	Umpher-3rd	28-05-87	4	0	Fisheries
Umpher-3rd	24-05-87	1930	Umpher-3rd	18-08-87	86	0	Fisheries
Umpher-3rd	24-05-87	1932	Umpher-3rd	28-05-87	4	0	Fisheries
Umpher-3rd	24-05-87	1934	Umpher-3rd	08-06-87	15	0	Fisheries
Umpher-3rd	28-05-87	1940	Umpher-3rd	15-06-88	383	0	Fisheries
Umpher-3rd	28-05-87	1948	Umpher-3rd	08-06-87	11	0	Fisheries
Umpher-3rd	21-05-88	2410	Umpher-3rd	22-05-88	1	0	Fisheries
Umpher-3rd	21-05-88	2413	Umpher-2nd	06-07-88	46	+1.7	Angler
Cochrane R.	04-06-87	1653	Cochrane R.	05-07-88	396	0	Angler
Cochrane R.	04-06-87	1664	Cochrane R.	08-07-88	399	0	Angler
Cochrane R.	04-06-87	1768	Cochrane R.	03-08-88	425	0	Angler
Waterfound	19-06-88	2301	Waterfound	---07-88	-	0	Angler
Geikie R.	09-06-88	2498	Geikie R.	24-06-88	15	0	Angler
Geikie R.	----1987	?	Geikie R.	---06-88	-	0	Angler
Fond-Eliz F	07-07-87	1406	Fond-Eliz F	----1987	-	0	Angler
Fond-Eliz F	07-07-87	1417	Fond-Eliz F	----1987	-	0	Angler
Fond-Eliz F	05-07-87	1497	Fond-Eliz F	----1987	-	0	Angler
Fond-Eliz F	04-07-87	1507	Fond-Eliz F	05-07-87	1	0	Fisheries
Fond-Eliz F	04-07-87	1521	Fond-Eliz F	05-07-87	1	0	Fisheries
Fond-Eliz F	04-07-87	1524	Fond-Eliz F	----1987	-	0	Angler
Fond-Eliz F	04-07-87	1524	Fond-Eliz F	07-07-87	3	0	Fisheries
Fond-Eliz F	04-07-87	1551	Fond-Eliz F	05-07-87	1	0	Fisheries
Fond-Eliz F	04-07-87	1560	Fond-Eliz F	05-07-87	1	0	Fisheries
Fond-Eliz F	04-07-87	1562	Fond-Eliz F	----1987	-	0	Angler
Fond-Eliz F	05-07-87	1585	Fond-Eliz F	----1987	-	0	Angler
Fond-Eliz F	05-07-87	1591	Fond-Eliz F	----1987	-	0	Angler
Fond-Eliz F	05-07-87	1593	Fond-Eliz F	----1987	-	0	Angler
Fond-Eliz F	30-06-87	1704	Fond-Eliz F	----1987	-	0	Angler
Fond-Eliz F	30-06-87	1708	Fond-Eliz F	07-07-87	7	0	Fisheries

Appendix 9 continued

Fond-Eliz F	30-06-87	1711	Fond-Eliz F	----1987	-	0	Angler
Fond-Eliz F	19-06-87	1974	Fond-Eliz F	05-07-87	16	0	Fisheries
Fond-Gray Is	07-07-87	1393	Fond-Gray Is	09-07-88	367	0	Angler
Fond-Gray Is	29-06-87	1644	Fond-Gray Is	24-05-88	329	0	Angler
Fond-Gray Is	29-06-87	1686	Fond-Gray Is	06-07-87	7	0	Fisheries
Fond-Gray Is	29-06-87	1687	Fond-Gray Is	26-05-88	331	0	Angler
Fond-Gray Is	30-06-87	1729	Fond-Gray Is	----1987	-	0	Angler
Fond-Gray Is	30-06-87	1733	Fond-Gray Is	----1987	-	0	Angler
Fond-Gray Is	30-06-87	1735	Fond-Gray Is	19-06-88	354	0	Angler
Fond-Gray Is	30-06-87	1738	Fond-Gray Is	25-05-88	349	0	Angler
Fond-Gray Is	30-06-87	1746	Fond-Gray Is	----1987	-	0	Angler
Fond-Gray Is	29-06-87	1779	Fond-Gray Is	----1987	-	0	Angler
Fond-Gray Is	01-07-87	1864	Fond-Gray Is	25-09-87	86	0	Angler
Jackfish Bay	08-07-88	2076	Jackfish Bay	11-07-88	3	0	Fisheries
Jackfish Bay	08-07-88	2078	Jackfish Bay	11-07-88	3	0	Fisheries
Jackfish Bay	08-07-88	2081	Jackfish Bay	09-09-88	65	0	Angler
Jackfish Bay	08-07-88	2123	Jackfish Bay	11-07-88	3	0	Fisheries
Jackfish Bay	08-07-88	2200	Jackfish Bay	11-07-88	3	0	Fisheries
Jackfish Bay	08-07-88	2307	Jackfish Bay	11-07-88	3	0	Fisheries
Jackfish Bay	08-07-88	2316	Jackfish Bay	11-07-88	3	0	Fisheries
Yalowega R.	-	?	Yalowega R.	10-07-88	-	0	Fisheries
Yalowega R.	-	?	Yalowega R.	09-07-88	-	0	Fisheries
Yalowega R.	09-07-88	2020	Yalowega R.	12-07-88	3	0	Fisheries
Yalowega R.	09-07-88	2025	Yalowega R.	10-07-88	1	0	Fisheries
Yalowega R.	09-07-88	2025	Yalowega R.	17-09-88	70	0	Angler
Yalowega R.	09-07-88	2057	Yalowega R.	12-07-88	3	0	Fisheries
Yalowega R.	09-07-88	2057	Yalowega R.	10-07-88	1	0	Fisheries
Yalowega R.	09-07-88	2096	Yalowega R.	12-07-88	3	0	Fisheries
Yalowega R.	09-07-88	2096	Yalowega R.	10-07-88	1	0	Fisheries
Yalowega R.	09-07-88	2097	Yalowega R.	12-07-88	3	0	Fisheries
Yalowega R.	09-07-88	2099	Yalowega R.	10-07-88	1	0	Fisheries
Yalowega R.	09-07-88	2099	Yalowega R.	09-07-88	0	0	Fisheries
Yalowega R.	09-07-88	2101	Yalowega R.	12-07-88	3	0	Fisheries
Yalowega R.	09-07-88	2101	Yalowega R.	17-09-88	70	0	Angler
Yalowega R.	09-07-88	2101	Yalowega R.	10-07-88	1	0	Fisheries
Yalowega R.	09-07-88	2108	Yalowega R.	12-07-88	3	0	Fisheries
Yalowega R.	10-07-88	2110	Yalowega R.	17-09-88	69	0	Angler
Yalowega R.	10-07-88	2110	Yalowega R.	10-07-88	0	0	Fisheries
Yalowega R.	09-07-88	2152	Yalowega R.	12-07-88	3	0	Fisheries
Yalowega R.	09-07-88	2152	Yalowega R.	10-07-88	1	0	Fisheries
Yalowega R.	09-07-88	2161	Yalowega R.	12-07-88	3	0	Fisheries
Yalowega R.	09-07-88	2165	Yalowega R.	12-07-88	3	0	Fisheries

Appendix 9 continued

Yalowega R.	09-07-88	2167	Yalowega R.	17-09-88	70	0	Angler
Yalowega R.	09-07-88	2167	Yalowega R.	09-07-88	0	0	Fisheries
Yalowega R.	09-07-88	2168	Yalowega R.	10-07-88	1	0	Fisheries
Yalowega R.	09-07-88	2168	Yalowega R.	12-07-88	3	0	Fisheries
Yalowega R.	09-07-88	2169	Yalowega R.	12-07-88	3	0	Fisheries
Yalowega R.	09-07-88	2172	Yalowega R.	12-07-88	3	0	Fisheries
Yalowega R.	10-07-88	2173	Yalowega R.	12-07-88	2	0	Fisheries
Yalowega R.	09-07-88	2175	Yalowega R.	12-07-88	3	0	Fisheries
Yalowega R.	12-07-88	2191	Yalowega R.	12-07-88	0	0	Fisheries
Yalowega R.	09-07-88	2193	Yalowega R.	10-07-88	1	0	Fisheries
Yalowega R.	09-07-88	2193	Yalowega R.	10-07-88	1	0	Fisheries
Yalowega R.	09-07-88	2195	Yalowega R.	12-07-88	3	0	Fisheries
Yalowega R.	09-07-88	2197	Yalowega R.	10-07-88	1	0	Fisheries
Yalowega R.	09-07-88	2310	Yalowega R.	17-09-88	70	0	Angler
Yalowega R.	09-07-88	2311	Yalowega R.	10-07-88	1	0	Fisheries
Yalowega R.	09-07-88	2313	Yalowega R.	10-07-88	1	0	Fisheries
Yalowega R.	09-07-88	2313	Yalowega R.	12-07-88	3	0	Fisheries
Yalowega R.	09-07-88	2313	Yalowega R.	10-07-88	1	0	Fisheries
Yalowega R.	09-07-88	2111	Yalowega R.	25-06-89	351	0	Angler
Yalowega R.	10-07-88	2070	Yalowega R.	25-06-89	350	0	Angler
Yalowega R.	09-07-88	2315	Yalowega R.	10-07-88	1	0	Fisheries
Wheeler R.	16-07-88	2015	Wheeler R.	19-07-87	3	0	Fisheries
Wheeler R.	16-07-88	2047	Wheeler R.	19-07-87	3	0	Fisheries
Careen L.	26-07-87	1212	Careen L.	30-08-87	35	0	Angler
Careen L.	23-07-87	1303	Careen L.	24-07-87	1	0	Fisheries
Careen L.	24-07-87	1331	Careen L.	26-07-87	2	0	Fisheries

* +downstream movement
-upstream movement

Appendix 10. Computation for Petersen (single census) estimates for grayling in Waterfound River and Cochrane River at Bigstone Rapids in 1987 - 1988.

An estimate of the population size, N, is given by:

$$N = \frac{M\ (C + 1)}{R + 1} \qquad \text{(Ricker 1975)}$$

where

M is number of fish marked (from Table 10)
C is catch or sample (from angler catches, Table 13)
R is number of recaptured marks in the sample (Table 10)

Location	Number marked, M	Recaptures, R	Catch, C	$\left(= \frac{M(C + 1)}{R + 1}\right)$ N
Waterfound R	6	1	6 196	18 591
Cochrane R.	59	3	1 666	24 588

- approximate limits of confidence were obtained by considering R as a Poisson variable:

  from Table, when R = 1, lower limit is 0.1 and upper limit is 5.6 and when R = 3, lower limit is 0.6 and upper limit is 8.8.

- by substituting these values into the equation, confidence ranges are obtained:

  Waterfound River: 6 640 - 371 820
  Cochrane River: 11 176 - 163 922

Appendix 11. Computation for Schnabel estimate (multiple census) for grayling in Umpherville River in 1987 - 1988.

Sample at time t	Number caught, C_t	Recaptured, R_t	Number marked/less removals	Marked fish at large M_t	$C_t M_t$
1	7	0	7	0	0
2	3	0	2	7	21
3	12	0	10	9	108
4	9	2	7	19	171
5	5	0	5	26	130
6	9	4	5	31	279
7	3	1	1	36	108
8	3	0	2	37	111
9	5	0	5	39	195
10	2	1	1	44	88
11	5	2	3	45	225
12	3	1	2	48	144
13	18	0	17	50	900
		$\Sigma R_t =$ 11	67		$\Sigma C_t M_t =$ 2480

Population estimate $N = \frac{\Sigma (C_t M_t)}{\Sigma R_t} = \frac{2480}{11} = 225$

(from Ricker 1975)

-approximate limits of confidence were obtained by considering R as a Poisson variable:

-from Table, when R=11, lower limit is 5.4 and upper limit is 19.7. By substituting these values into the equation, confidence intervals are obtained (95% range):

126- 459